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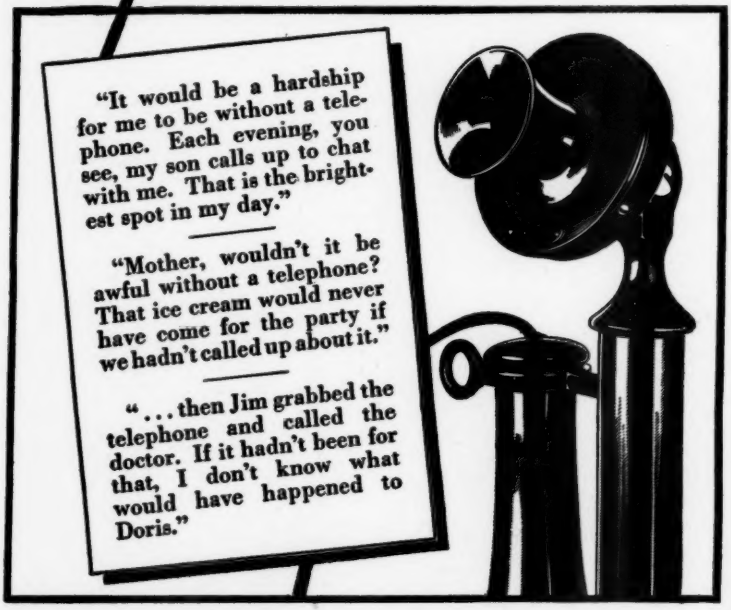
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A CALL FOR ACTION

By B. M. BRIGMAN, *Vice-President,*

Dean, Speed Scientific School, University of Louisville

President Wickenden in his salutatory editorial, "The Times Call for Teamwork," gave us food for thought. We do face conditions heretofore undreamed, and it is only through *teamwork* that we can solve or make lighter the problems that confront us.

On every turn we have seen industry demoralized; we have watched the index charts go down and down; we have seen the bread lines and the introduction of the relief measures for unemployment. All of these are depressing. The effect upon our educational institutions is likewise depressing. It is obvious, of course, that education should bear its portion of the burden in the consequent reduction of income. No valid argument can be advanced which should give the teacher's salary priority in the required and necessary financial readjustment. It is, however, to be deplored that in this financial readjustment the school systems throughout our land have been made to suffer more severely than other divisions of the states and cities.

The child in the primary grade to the student in the university is a *growing* body. This growth cannot be retarded; neither can it be stopped. The child is continuously growing. What is lost or denied during this period cannot be regained. What sacrifices must be made should not be made at the expense of this critical period. An enlightened citizenship is the goal of education. These young people are the bulwark of our civilization. What we *do* or *do not* will be the unit by which our generation will be measured. Whatever the future holds in store, whether it be chaos or progression, our purpose should be to provide for the educational needs of our youth to the end of our means.

In a recent discussion on the now all too familiar subject of "economic conditions," an industrialist was volubly expostulating on the fact that his factory was "in the red" and that the "college professors did not know how well-off they were." The question was asked of him, "Shall we close the schools and colleges until normal conditions return, and then take up the educational programs again?" "Of course not," he replied, "but the schools and colleges can cut down expenses by 'running half-time' like the rest of us." When he was asked in return if the development

of the child could be retarded "half-time," he graciously admitted that he *forgot* that "the child was growing all the time."

Can it be then that those who control or administer the funds for educational purposes have forgotten or lost sight of the fact that youth *is* growing all the time?

Since the efforts of the nation are concentrated upon rehabilitation, it appears that it shall be left to us to champion the cause to which we are dedicated. We cannot afford to be idle. It may be pertinent to inquire what has become of the movement to advance tuition to students from the Federal Emergency Works Administration funds, or why it is that the National Industrial Recovery Administration has not made provision to care for the educational requirements of those children whom it has so meritoriously relieved from labor? In other words, what thought is being given to education?

We face a New Year, one which is charged with problems that will demand impeccable thought and action upon the part of all good citizens. Our part in this great problem seems very definite and clear-cut—we must keep our educational institutions intact and minister to the needs of the times.

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CAN INVENTIVE ABILITY BE DEVELOPED IN ENGINEERING STUDENTS?*

By GEO. M. BARTLETT,

Professor of Machine Design, Purdue University

The frequency with which this question has been asked during the past few years and the seriousness with which it has been entertained by some suggests that the subject might profitably be discussed by those interested in engineering education. Before entering upon the pros and cons of the main question a brief discussion of the general subject of inventions and inventors may be desirable, and we will first enquire as to what constitutes an invention, what are the characteristics of the successful inventor, the various occupations and types of inventors, and the effect of heredity in the making of an inventor. Then the processes of producing an invention will be listed, as well as certain pitfalls met by the inventors. Finally, after determining which specific aptitudes of an inventor must be inate and which can be developed by the educational process, we will discuss the possible ways and means by which those found to be naturally inventive might be given special training to hasten or complete the desired process of development.

In the preparation of this paper I am much indebted to the author of "The Psychology of the Inventor," Dr. Joseph Rossman, United States patent examiner, for many interesting facts about inventors and the results of several questionnaires sent out by him, and which throw light upon the topic in question.

What Constitutes an Invention? Briefly, an invention is a novel device capable of serving a useful purpose. A new kind of chart, a new mathematical process (logarithms—calculus) a new method of teaching a particular subject, a new plan of organization, a process of doing something, a universal language (Esperanto) an electrical, optical, hydraulic or mechanical device, may constitute an invention in the broad sense provided it has come into being by the exercise of that creative faculty known as inventiveness.

The following processes are not considered to constitute inventions in themselves: Reasoning; mere logical deductions or con-

* Presented at Machine Design Session, Annual Meeting of S. P. E. E., Chicago, Ill., June, 1933.

clusions from certain admitted premises; the exercise of ordinary mechanical skill; the making of parts stronger or lighter, or duplicating them; changing the size or degree of a thing, omitting certain parts, changing their location, making them integral or adjustable, substituting for them a known equivalent, or using a different material.

Neither is skillful design necessarily invention, for design is merely *aggregation*. It has been said that in design two and two make four; but in invention two and two make more than four, since invention is the putting together of parts *with a new result*.

What is an Inventor? An inventor is one who creates by the operation of the mind new means of attaining a certain specific end which was hitherto unknown to himself or to the world, at least in the particular combination or conjunction in which he causes them to exist for the first time.*

Who Does the Inventing? In the past most of the important inventions were made by men trained in other fields. A barber invented the spinning frame; a clergyman invented the power loom; an instrument maker invented the improved steam engine; a portrait painter gave us the steamboat, and a lawyer conceived the idea of the cotton gin. These things were possible in the earlier days because technical knowledge was very limited and it was easy for a man of intelligence to acquire in a short time all the technical knowledge necessary for invention in any field. To-day technical knowledge has greatly increased; the number of devices requiring technical knowledge has increased, and there is a greater need for more specialists to cover the various fields of knowledge. Also most of the great inventions requiring a knowledge of only the commonly known principles have already been made, and as a result most inventions in the present age are made by men actively engaged in the fields to which these inventions relate.

There are notable exceptions to this rule, however, as even to-day some of the most valuable inventions in a given field have been made by men from other fields. Why, Dr. Rossman asks, didn't a farmer invent the reaping machine, or a carriage maker invent the automobile, or a tailor the sewing machine? Why didn't a quarry owner or a mine superintendent invent the rock crusher? Why didn't a professor of physics or an electrical engineer invent the telephone? and why didn't a southern cotton planter or mill owner invent the cotton gin? "The reason," he says, "can be explained on several grounds. A man inexperienced in a given field often has a distinct advantage over those who are experienced in that field. He has nothing to lose, his professional reputation is not at stake, he can tackle his problem without any preconceived

* See Dick *vs.* Fuerth, 57 Fed. Rep. 834.

notions or theories, and he is free to form his own theories or possible solutions. He is not bound by any traditions or precedents, and there are no authorities that he is bound to respect. Hence he is less likely to follow an old groove and he has a fresh and unhampered outlook on the problem."

Out of 710 inventors of to-day 60 per cent were found to be engineers, about 24 per cent were executives, 5.4 per cent were mechanics, 2 per cent were professional inventors, and 9 per cent were miscellaneous. It is quite likely that among the 24 per cent who classed themselves as executives a large proportion were engineers who had been promoted to executive positions.

When 452 inventors were asked whether all of their inventions were confined to their regular line of work, fifty per cent answered Yes, and fifty per cent answered No.

Occupationally there are two classes of inventors: (*a*) the individual inventor and (*b*) the group inventor who is hired by some large industrial organization to work in coöperation with others for the purpose of making improvements in the particular products of the organization, or in the processes for fabricating those products.

Individual inventors are of various types, such as the old-fashioned "Yankee type" (Howe, Whitney, Goodyear, Morse) who uses the cut-and-try method and relies mainly upon his native ingenuity; the "free lance" inventor; the "casual inventor" who invents when the need arises or when the spirit moves him; the "professional inventor" who makes inventing his sole business; and the "industrial inventor" who as a manufacturer invents to improve his products, to decrease the cost of fabrication, to improve his methods or his machinery, or to surpass his competitors in some way.

The Yankee inventor has given us most of our basic inventions. The free lance inventors are usually unsuccessful imitators of the old-fashioned Yankee type. The professional inventor is usually a technically trained man and with a large and varied fund of information. He may work alone or have a staff of assistants, and he rarely engages directly in the manufacture and sale of his inventions. Edison was probably the first inventor of this type.

The group inventor differs from the individual professional inventor chiefly in that he is employed by a commercial organization and is expected to confine his talents to inventions relating to the particular products in which the organization is interested.

Dr. Wm. M. Grosvenor, writing under the title "The Seeds of Progress," compares the products of the pioneer inventor working independently with the inventions developed by research in the

laboratories and shops of our large industrial corporations. He says "Thirty years of observation and research in patent matters convince me that the proportion of *revolutionary* improvements initiated by corporations is relatively small. I have seen the lines of progress that were most promising for the public benefit wholly neglected or positively forbidden just because they might revolutionize the industry." This is as one might expect, for corporations are not altruistic institutions, and a pioneer invention, however valuable it might be to society, might if adopted mean the scrapping of many thousands of dollars worth of machinery and equipment. Due credit is given to these big corporations for the valuable results of development research, but for real pioneering and the production of revolutionary inventions one must always look to the "crazy fellows" who work independently and produce such epoch-making inventions as wireless telegraphy, flying machines, the monotype, motion pictures, the Deisel engine, the submarine, the safety razor, Bakelite, etc.

A tabulation of 72 outstanding inventions made since 1889 shows that only 12 were produced by corporation research, the other 60 being brought out by free and independent workers who possessed, along with the other necessary qualities, the ability to resist ridicule and criticism. The time was, as Dr. Grosvenor remarks, when railroads were absurd, steamboats were unsafe, explosives dangerous to use, wireless merely a scientific curiosity and flying machines were demonstrably impossible. Had the recognized authorities of former periods always had their way instead of the pioneer inventors, we would to-day be enjoying but few of the luxuries of this wonderful age of progress.

Characteristics of Inventors.—There are differences of opinion as to whether inventors have any peculiar traits different from the average person. Dr. Rossman asked 176 patent attorneys the question "Are inventors different from non-inventors." Forty per cent replied yes, and sixty per cent no. But when called upon to give the outstanding characteristic of inventors the replies show that successful inventors differ distinctly from non-inventors in the degree to which they possess certain important characteristics. First of all the nature of their reactions toward imperfections in things as now produced and the inconvenience in our ways of doing things is different. One class of people would go calmly through life quite satisfied with things as they are, and without realizing that many things could be improved. Others realize the possibilities of improvement, but never think of themselves as possible agents in bringing into existence new creations. Some spend their energies criticizing things as they are and also all proposals for betterment, while a few, a very few, will attack

with courage and confidence any problem whatsoever, the solution of which they believe to be worth while. They take the attitude that if a thing is imperfect or an operation is inconvenient there must be some way to improve it; and their immediate impulse is to study the problem in order to discover why the difficulties exist and to find a better way. Whatever criticism this class has to offer is constructive criticism. Among this class alone are inventors to be found.

But aside from this attitude toward his environment the successful inventor must be a man of intelligence with sufficient confidence in himself and interest in his problem to get him started, and with the indomitable patience and perseverance to keep him at it in the face of apparently insurmountable obstacles.

With further reference to Dr. Rossman's questionnaire * I have compiled a composite of the opinions of 176 patent attorneys, 78 research directors, and 710 successful inventors, assuming that the average opinion of each group should have equal weight. This gives us the following thirteen characteristics as the leading ones in the opinions of these three groups.

Characteristics	Index of Relative Importance
1. Perseverance	135
2. Originality	105
3. Analytic ability	102
4. Imagination	93
5. Observation and curiosity	34
6. Self confidence	34
7. Knowledge and memory	26
8. Reasoning and intelligence	26
9. Training and education	26
10. Business ability	23
11. Common sense	19
12. Mechanical ability	9
13. Optimism	7

Other qualities mentioned as important characteristics are:

Patience—Tenacity of purpose—Ability to resist ridicule and criticism.

Resourcefulness—Versatility—Ingenuity—Freedom from the hampering effects of tradition—Creative talent—Ability to combine facts to create something new—Synthetic ability.

Perspicacity (acute discernment).

Spatial imagination—Ability to visualize or to build something in the mind—Ability to conceive things which have never been seen and which have never existed—A feeling for dynamic and kinetic relations directly rather than through mathematical analysis.

* "The Psychology of the Inventor," Chap. IV.

Willingness to throw away years of endeavor and research without regret and completely re-design the idea to fill certain demands —A belief that finality has not been reached in anything—Idealism.

Broad knowledge as to how to find answers to enquiries.

Good judgment—Sanity—Ability to eliminate all unnecessary details.

Draftsmanship.

Business sagacity and shrewdness—Ability to sell an idea.

An examination of this list will show that many of them are synonymous or express similar qualities in different words. It is not unlikely that if the men who helped to contribute the first list of 13 characteristics had originally possessed the entire list of 41 suggestive terms the composite list would have been somewhat different, and perhaps arranged in a different order.

The following statements regarding the qualities of inventors are interesting because they come from men who are themselves experienced and successful inventors:

Dr. Elihu Thompson, who has been granted more than 700 patents, states that the successful inventor "should have a habit of mind in which obstacles are regarded as things to be overcome instead of backing down in face of them."

Dr. Reginald Fessenden, who has over 500 patents, emphasizes a good memory, infinite patience, a good working knowledge of mathematics, and the ability to work 18 hours a day for months without tiring.

Emile Berliner emphasizes thoroughness, patience, perseverance, industry, and hard work. "The inventor," he says, "must be content to work for months at a time without making any apparent progress. He must be content to travel over the same field again and again and again, indefatigably. That is the secret of the inventor's success—never-ending application. The idea that an inventor is necessarily a genius is entirely fallacious. Genius for invention is merely the capacity for concentration and for work. Given these qualities and a power of close observation and you have the make-up of a successful inventor. He need be no learned scientist, and yet he may be able to work up most valuable inventions in many sciences. He need be no perfectly trained electrician, and yet he may be able to work up a valuable electrical appliance. But always he must be prepared to take advantage of new phenomena and to know all about the field in which they lie. Many of our most important inventions are the result not so much of deep knowledge as of the power of observation and the ability to appreciate the possibilities of phenomena that the less observing would pass by without seeing." (*Sci. Amer.*, 1902, 86, 242.)

Another successful and prolific inventor, Mr. David E. Ross,

emphasizes curiosity, tenacity of purpose, ability to dream and to concentrate (but this concentration, he states, must be broken by periods in which the problem is entirely dismissed from the objective mind), ability to resist ridicule and criticism, ability to convince others of the soundness of one's ideas, and ability to make a disinterested appraisal of the utility of an idea and willingness to abandon it if it is found to lack superiority.

Actual Methods of Inventing

Another interesting and important study made by Dr. Rossman relates to the actual process by which the average invention is developed in the mind of the inventor. Replies to his questions came from 710 inventors having an average of 39.3 patents. A composite of the replies received indicates that the average procedure in inventing consists of the following seven steps:

(1) *Recognition* of a need or a difficulty (observation).
(2) *Analysis* of the need (to determine exactly what he wants to accomplish, whether it be simplification, increased efficiency, decreased cost, automatic operation, safety, or greater accuracy).
(3) *Survey* of all available information (technical literature, patents, conferences, study of all existing methods).
(4) *Formulation* of all objective solutions (study of all possible ways to accomplish the end).
(5) *Critical analysis of these solutions* for their advantages and disadvantages (this involves logic, good judgment, good reasoning).
(6) *The birth of a new idea*—the invention—the inspiration—the visualization of the solution—use of the creative faculty.
(7) *The development of the idea* into a practical form—experimentation—model making—selections—rejections—study of causes of failures—design and construction.

This is far from being a correct representation of the method pursued by all inventors. Some omit step number 3 in whole or in part, believing that a knowledge of what others have done may make it more difficult for their minds to work along new paths and toward original solutions.

The following statement concerning invention is attributed to Mr. Thomas A. Edison: "Invention is the hardest kind of work and requires intense application of every faculty. There is no guesswork about it. There is no unfailing principle of luck in it. The goal must be reached by a process of elimination. Every factor must be studied, examined, and then eliminated if it is not what you want, until you have narrowed the entire problem down to

two or three points. Then it is possible that luck or accident may play a minor part, and some day the whole thing will dawn upon your mind and you see the goal you have been looking for."

This last part of the process as described by Mr. Edison corresponds to step number 6 in our tabulated procedure. Much has been written on the nature of the psychic process involved in this step, which to the inventor himself is the thrilling moment toward which all of his previous work has led. Up to this time he has been thinking, reasoning, concentrating, visualizing, building up mental pictures of complicated solutions, rejecting them, and interspersing all with periods of rest in which the whole problem is dismissed from his consciousness. Then, perhaps after weeks, perhaps months, or even years, there comes to him during one of these quiescent periods a mental picture of the solution to his problem. He is amazed by its simplicity and astonished at not having been able to find such an obvious solution before.

The conditions most favorable to this psychical event vary with the individual. The bright idea may come while dressing, shaving or bathing, while walking in the woods or at the seashore, while listening to a lecture, a sermon or a concert, or, as frequently happens, in the early morning, an hour or so before the usual time to arise, when the mind is on the threshold between sleeping and waking, and not under any sort of excitement. The subject comes to the mind uninvited. It is not called up by an act of the will, nor by a conscious wish, nor by a suggestion from without; but it floats along the stream of thought and into the mental vision like driftwood on a quietly flowing river. If it does not arouse the interest it passes away and is replaced by other subjects. If it is of interest it lingers as though accepting an invitation to tarry. The mind awakens slightly and gives attention to the subject which now presents itself in such an amazingly simple form that the difficulties which were formerly present are swept away and the solution to the problem seems perfectly clear. To arouse oneself at this point for the purpose of finding a pad and pencil and making a record of the solution may have the effect of ruining the picture by partially erasing it from the memory. Oftentimes it is possible to hold the subject before the mind without awaking, and, by putting the solution into words and repeating them over and over while still in the semi-conscious state, the impression thus made will be strong enough to hold over until the percipient has naturally awakened and is able to make his written record.

Obstacles met by inventors through no apparent fault of their own have been named in the following order of the frequency of their occurrence.

Lack of capital	136
Lack of knowledge	93
Prejudice of the public	69
Legal difficulties	55
Marketing	54
Anticipation by others	39
Lack of time	38
Lack of facilities	23

Pitfalls which inventors are advised to avoid are mentioned by the 710 inventors previously referred to, and in the following order of their frequency.

Impracticability	166
Overconfidence	120
Lack of knowledge	112
Unscrupulous patent attorneys	72
Lack of thoroughness	46
Dishonest promoters	43
Discouragement	30
Hope of riches	28
Disclosure to others	23
	710

The limitations of this paper do not permit an extended discussion of these obstacles and pitfalls, but each eloquently suggests stories of grief and failure.

Hereditary and Environmental Influences.—There is no evidence to show definitely that either heredity or environment is alone responsible for inventive ability. Heredity and environment are generally regarded to-day as complementary factors which mutually interact to produce the characteristics of all individuals. Heredity supplies the characteristics which make the environmental influences potent for one or another type of development through education or training.

In the case of the inventor, what he inherits is (*a*) an adaptability to certain kinds of environment; (*b*) the capacity for mental development by education and training, and (*c*) certain types of ability which make up the inventive mind, such as the capacity for tedious detail and prolonged mental concentration. It does not follow that because an individual possesses the necessary hereditary traits, he will develop them in connection with an uninspiring environment. The kind of an oak tree into which an acorn will grow depends partly upon the tree from which it came, and partly upon the nature of the soil and climate in which it is grown.

That the hereditary element is important is shown by the following results of investigations:

Galton found that in a group of 977 eminent men there were 739 relatives of eminence. Havelock Ellis and J. M. Cattell made

studies from which similar conclusions were drawn; and Dr. Joseph Rossman found that out of 710 inventors the fathers of one third of them were professional men (20 per cent of whom were engineers): 35.5 per cent were of the commercial class, 16.2 per cent were skilled laborers, and 15 per cent were farmers.

Of 447 inventors, two thirds were found to have grown up children who were also inventors.

When the children of eminent men also become eminent, and the children of inventors become inventors it is a question whether the immediate environmental influences should not be given their due share of credit since such children are brought up in an atmosphere quite favorable to careers of eminence.

Training Inventors.—In the past it was possible for inventive minds to create epoch-making inventions without special technical knowledge. In the future, important inventions will depend more and more upon technical knowledge on the part of the inventor or his associates. But a technical training will not alone make an inventor. Indeed there are those who believe that the conditions in our technical schools tend to suppress whatever originality a student may have formerly possessed. One reason for this may be that analysis and synthesis are reverse processes, and in technical training the emphasis is almost exclusively upon the former. To take apart and study something that has already been made or described is analysis; but to assemble various parts into new and useful combinations that have never before existed is synthesis. It is the basis of invention. Also, in technical training emphasis is placed upon the correct processes by which desired results are reached. In invention the *process* is of no importance so long as the *end* is attained. The student who has a natural aptitude for original thinking often feels impelled to exercise his creative faculty on anything that comes his way; and when it happens to take the form of an improvement (?) on some time-honored formula or mathematical demonstration in the educative process, let him beware the tutorial ire! Or should we say, Let the instructor beware lest he discourage the growth of a rare and commendable quality?

In an address before one of the local meetings of the S. P. E. E. Professor R. E. Doherty says, "There are too many engineering technicians and too few creative thinkers." And to this, *Product Engineering* (March, 1933) remarks that "Facts and formulas and their manipulation are well taught in our engineering schools, but their application to the solution of a comprehensive engineering problem is something that cannot be done by rules, but only through complete engineering analysis and original thinking."

How can a technical school combine a proper training in engi-

neering analysis with creative thinking? They who give much serious thought to this question are bound to meet a number of difficulties. Some favor a special school for the training of inventors in which an elaborate curriculum would be laid out and special laboratories and shops provided for the use of the would-be inventors. Others would begin the training of the inventor at a very early age, say as soon as he shows the first inclination to tinker or to originate new ways of doing things. Some would take all applicants who think they would like to become inventors. Others would carefully select the candidates for admission by the application of severe tests to determine general intelligence as well as mathematical, chemical and mechanical aptitudes. Also an investigation would be made as to special traits exhibited during earlier years.

Laying aside the idea of a special school as something too advanced for our present discussion let us confine ourselves to a consideration of the simple question as to how a technical school can combine a proper training in engineering with such additional training as would be helpful to those possessing inventive ability.

Referring to the list of 13 characteristics as previously named, which of them are already emphasized in engineering courses? which could be developed by special courses? and which must be born in the individual or come as a result of very early environmental influences? Perhaps most of us would agree that the following characteristics receive sufficient attention in regular engineering courses:

Analysis	Mechanical ability
Technical knowledge	Reasoning

The following characteristics do not seem to develop much by teaching. A successful inventor must acquire them through heredity:

Perseverance	Intelligence
Memory	Common sense

The following characteristics must also be hereditary, but it is probable that, like musical and artistic abilities, they can be more rapidly developed by a course of training under the proper masters than if left to develop more or less by chance:

Originality	Observation
Imagination	Self-confidence

Engineers who have become successful inventors have testified to the value of descriptive geometry in developing spatial imagination of just the right sort to aid them in carrying the pictures

of a problem in the mind and developing it according to their whims. Let us have a special advanced course in descriptive geometry for students with inventive minds.

An engineer who has become a professional inventor recently stated that until his senior year in college he had not known that he possessed any special inventive ability excepting that as a boy he had always been fond of tinkering with various mechanical devices about the farm. His interest was awakened by the fact that one of his professors was in the habit of proposing an occasional inventive problem for the students to work upon. He found that he was one of the very few who could solve such problems, and he believes that the stimulating effect of such a course upon the minds of students possessing natural creative ability is well worth while. This, then, is the way to stimulate and develop originality. But unless all of the members of the class have exceptional inventive ability to start with, the time will be largely wasted upon the majority. Moreover there will always be some in a miscellaneous class who cannot be shown wherein their solutions are impractical, and much of the instructor's valuable time may thus be spent upon those unable to profit by the training offered. The proper procedure would seem to be to offer a special course in invention to those students who have been selected on the basis of psychological tests and their former grades in descriptive geometry, mechanical drawing, mathematics, physics and mechanism ;and to give these students a number of well selected inventive problems which require observation, imagination and originality for their correct solution, and especially problems involving the synthetic process.

To illustrate this latter, such a problem as the following might be proposed: A manufacturer wishes to perform several operations upon a metal part automatically. It is necessary that the part be carried by a plate to which it is clamped, and then moved along the four sides of a square, stopping for a few seconds at each corner, and always remaining parallel to its first position. Design the mechanical movements for bringing this about.

The student in his study of the kinematics of machines, has become acquainted with cams, the Scotch yoke, the double universal joint, Oldhams coupling, the principle of the universal drafting machine, the quick return motion and the Geneva intermittent motion. He is now required to draw upon this supply of material for the necessary means whereby he can get the required motion for this part. His solution must be practical, simple and efficient, and the working parts must be so arranged as to avoid interference.

Obviously there are a number of possible solutions to such a problem as this, and a discussion by the students as to which proposed solution is the most practical is likely to be stimulating. A series of such problems which do not lead to anything patentable are probably best for class work, and they may cover a range sufficient to include the use of nearly all known mechanical movements.

It is questionable whether much would be gained if students having ambitious projects of their own were allowed to work upon them in preference to those assigned by the instructor, since the main purpose is the exercise of the students' minds upon a variety of problems covering a wide range of thought.

The course should also include the study of certain great inventions, the methods of successful inventors, the procedure in applying for a patent, some facts about patent law, the reading of certain interesting court decisions involving patents, and some talks by patent attorneys and successful inventors.

The purpose of this paper has been to treat more or less briefly several phases of a subject that is interesting to many and that presents an educational problem by no means easy of solution. The hope is that by discussion and practical demonstration some of us will in the near future be able to answer the question: Can inventive ability be developed in connection with an engineering course, and is it worth while?

SUITABILITY OF TEXTS ON MACHINE DESIGN

By FRANK L. EIDMANN

In view of the number of criticisms which have been made of texts on Machine Design, discussions were invited in the Machine Design Clearing House. This group is comprised of over 90 teachers of Machine Design in 82 colleges in the United States and Canada for the purpose of considering problems relative to the teaching of Machine Design.

Excerpts from some of the discussions on the above subject which appear in a recent seven page bulletin of the Clearing House are quoted below. Copies of the bulletin may be obtained without charge from the chairman, Frank L. Eidmann, Columbia University.

From the discussions it is apparent that there is a considerable divergence of opinion as to what should be taught in a course in Machine Design. Naturally, then, no single textbook would be suitable. In some institutions the course consists largely of a description of the various common machine elements with a consideration of their typical applications and empirical methods of design. On the other hand, with the growing use of high speed machinery, and with the many new materials of construction which are available, and with the great advances in engineering practice during the past decade, some teachers believe that a more advanced treatment of the subject should be presented. For this purpose texts of a more advanced nature are needed with fundamental considerations so that unusual cases in design may be dealt with.

Among the most frequent criticisms made by the discussors were: (1) the use of empirical formulæ instead of basing design work on fundamental conceptions; (2) lack of attention to latest standards; (3) too much data taken from commercial catalogs and old textbooks without verification for accuracy.

* * *

"It is certainly true that there is no suitable text available for a class of students which, I feel sure, is a fairly large one, namely, that comprised of senior mechanical engineering students whose preparation has included a good training in mathematics, physics, mechanics, kinematics, mechanism, mechanics of materials, shop practice, testing laboratory, and some metallurgy.

"If, from available texts, the material already covered in the above courses is deleted together with tables reprinted from handbooks, there is practically nothing left but shop kinks. Many texts condemn themselves in the prefaces by claims to the effect that the texts are mathematically painless. They are really adapted to high school intelligence. I have been told, but hardly believe it to be true, that this plan is adopted so that the instructors themselves will be able to understand the texts and possibly use them."

* * *

"To present problems in such a way as to give the student some review of his mathematics and to illustrate how his theory can be applied to practical problems require considerable skill on the part of the teacher and the author of the text.

"This is a point which, in my opinion, some authors of machine design textbooks handle rather poorly. Many times in his study the student suddenly comes to a formula and, if he is at all conscientious, wants to know how it was derived. It is obvious that in a machine design textbook the author should not show how every equation is derived, but if he would give a reference to some text where the student can find the derivation it would be a great help to the student and many times to the instructor as well. The proper reference should also be made concerning all empirical equations used."

* * *

"A text of Machine Design and especially one to be used in first classes should deal much with fundamental problems. It is not necessary to include in such a text a discussion of Mechanics, Mechanism and Strength of Materials. These subjects should have been studied prior to taking up machine design which is of course an application of these subjects to the design of Machine Parts.

"Many writers like to include a great deal of material along lines in which they have made special investigations or for some reason have a special interest. All this is good but has no place in a general text. Such material is splendid for a reference library."

* * *

"In a general way, based on thirty-eight years of experience in teaching Machine Design, I might deprecate the tendency of the production of 'high-spots,' commercial-catalog-illustrated (so-called 'practical') texts . . . with no particular attention paid to

training in fundamentals, particularly in constructive, inductive reasoning. Handbooks have their place, but a text is not an attenuated handbook. A textbook should have as its guiding principle *training* in mental processes, methods of approach, solution, etc., rather than an aim to peddle a bit of *information.*"

* * *

"I am not satisfied with most of the textbooks on machine design at present on the market. The first criticism is that many of them are not up to date. There have been great developments in practice and also in the application of fundamental theories of mechanics, etc., to design in the last ten or fifteen years. A large part of this material has not yet found its way to standard textbooks.

"I also feel there is too much tendency to use formulæ which to the student are empirical rather than to base the theories of design on fundamental conceptions. Frequently these formulæ are useful only in specific cases. It seems to me that the emphasis should be on analysis so as to develop power in the student to take care of unusual cases, rather than to simply drill him in the methods of solution of standard problems."

* * *

"Previous discussion has indicated considerable divergence of opinion on what the specifications for a good text on machine design should be. It appears that this divergence is a natural consequence of difference of opinion on what a good course in machine design for undergraduates should be. One school of thought assumes that the aims of such a course should include acquainting the student with the details of construction and methods of design of all important modern machinery. For such a course the five hundred page text, however accurate and well-written, must of necessity be sketchy and inadequate. Further, the time made available for this subject in most curricula makes such a course impossible even if it were desirable.

"In my judgment the first aim of a course in machine design should be to give a student practice in the use of his mathematics, physics, mechanics and materials of construction and thereby deepen and broaden his workable knowledge of those fundamentals. The choice of the portions of the field of machinery to be treated is important but secondary."

* * *

"I think it can be said that texts in Machine Design give evidence of being hurriedly prepared and not sufficiently examined for obvious errors before being printed. Some of these texts show that the authors have a special interest in one or two phases of the subject and have presented original treatments of those parts which relate to their hobbies, the rest of the book being made up of material borrowed from older texts without any apparent investigation as to whether it is up to date."

"There is a tendency on the part of some authors to make up the bulk of their text from tables, charts and other data taken directly from commercial catalogs, without considering that such data are often non-technical and that they are designed to make the product of The John Doe Co. appear stronger or more efficient than that of the Richard Roe Co. Where such data are used the author should make sure that they are the result of the application of sound engineering principles, or that they are backed by unquestioned good authority. Empirical formulas appear in recent texts bearing errors that have been copied from older texts, the authors not having taken the pains to check up on their correctness."

* * *

"The first objection to textbooks on machine design that comes to mind is that so many of the best ones are full of obsolete material in the form of old standards. This may be considered a minor objection, but it directly concerns publishers who must encourage their authors to revise the texts often enough to keep the material up-to-date. A second and more serious fault is that generally the arrangement of material seems to be without plan or reason."

* * *

"It seems to me that for required undergraduate work a design course should consist primarily in the application of the fundamental principles of dynamics and strength and resistance of materials to machine parts. If we look over the industry, we find very few college graduates actively engaged in machine design and I am convinced that this is due to the fact that the majority of the colleges are not offering anything in design which a good man cannot derive from a careful scrutiny of reference and handbooks. The vast majority of machinery designed to-day is designed on the handbook basis with the assumption that an experimental machine will be built and tried out to see if it is satisfactory. If not, changes are made until the machine is satisfactory. This process

without doubt costs far more than a thorough analysis prior to building the first machine."

* * *

"I am distinctly dissatisfied with the present textbooks in Machine Design. I do not believe they teach *design*. There is no balance between the material presented. Even if the subject matter were balanced what can be covered in 400 pages, but most elementary information? It all comes to the question how design should be taught.

"It must be remembered that *no* textbook can be sufficient to teach machine design and it would be a hopeless task to prepare such a book. It would be obsolete a year after printing. The instructor must do the teaching, using models, albums, drawings in trade magazines, etc. The textbook can be only a manual. This being the case, there is only room for basic information in the textbook. To illustrate let us take *shafting*. The chapter should contain: twisting of shafts; permissible stresses and materials used; effect of keyways; standard sizes of keys; various uses of keys; effect of fillets; fatigue failure and stress concentration; crank shafts; vibration of shafts (elementary); torsional vibration (simplest formulæ); turning of shafts and use of steady rests; accuracy of turning; finishes required for various typical applications; press fits, slide fits, shrink fits. All the rest about shafts must be shown on actual shafts, a collection of which should be assembled in a museum of machine design. If analogous information regarding other standard machine elements were given, there would be little room for complaint about textbooks in machine design for several years to come."

A COURSE IN GENERAL ENGINEERING

By PAUL CLOKE,

Dean, College of Technology, University of Maine

Civilized man in his struggle toward an ideal existence has had held up to him ideals and objectives which have met the conditions of the times, but which as time went on changed and were displaced by new ideas and goals.

Aristotle, in his *Politics*, said:

"No low mechanic ought to be admitted to the rights of a citizen, nor any other sort of people whose employment is not productive of virtue."

Plato, in his "Study of the State," says:

"Mean employment and manual arts are a reproach. The soldier who leaves his comrades or throws away his arms should be degraded into the ranks of a husbandman or an artisan."

For many centuries the torch of education was carried forward by monks in monasteries with a predominantly religious motive. The guilds of the middle ages, probably the forerunners of our trade unions, were designed to further commerce, handicrafts, and various business enterprises.

In America George Washington was one of the first to emphasize the necessity of education for the masses as being the most effective means for preserving a democratic form of government.

Abraham Lincoln was probably the first President of the United States to take serious issue with the point of view expressed by Aristotle and Plato. Perhaps we have swung too far on the material side in these latter days in America. Certain it is that in the early days of the Republic during the times of political or financial stress, the leaders gave increased emphasis to education but we, not understanding the causes of the depression, strike out blindly against the schools as if that would save us from our dilemma.

The modern American University represents an attempt to harmonize many educational ideals and objectives.

"The basic trouble of the modern college is that, like Stephen Leacock's horseman, it rides off in all directions at once."

It seems to me that another Greek philosopher, not so well known, recognized even at that early date, the true aim of education in any age.

"The truly educated person is the one who understands and is able to adjust himself to the civilization in which he lives."

In an editorial which I wrote for the *Journal of Engineering Education* last fall—"The Signal Light Shows Clear"—I pointed out that engineering educators knew where they were going and were on their way. Some of my friends took me to task as preaching a doctrine of *status quo*. Far from it. I do believe that engineering education fits a man to take his place in modern society as well as to follow a particular engineering field. First, we teach fundamentals in English, mathematics, and science. We include economics and sociology not alone as subjects in themselves, but as part and parcel of the engineering work itself; and thirdly, we endorse the study of the humanities which, as do engineering subjects, broaden a student's outlook and perspective on life.

Professor E. W. Marchant in his inaugural address as President of the Institute of Electrical Engineers of Great Britain, expressed himself in a very similar manner as follows:

"It is a common complaint that the scientific worker is made subservient to the business organizer and administrator. That will always be likely to happen unless the scientific worker manages to secure a decent education; otherwise he will inevitably become simply a technician, working in a laboratory overall, instead of a workshop overall, but simply taking the place of the old craftsman. The remedy lies in our own hands. It is to discourage early specialization at school and exclusive specialization at college. To insist, instead, at any rate that the higher degrees in science should connote a good level of general education."

Dean Leland, in an address before the engineering section of the Land-Grant College Association last November, made this statement:

"The professional courses in engineering are so broad in their fundamental training that graduates frequently enter lines of activity which are not directly concerned with engineering practice. Many engage in business occupations which, while not strictly technical in character, require an engineering foundation. Then there is the great field of executive and administrative work from subordinate positions to those demanding the highest ability and generous experience—it is not unusual for a businessman to send his son to an engineering school in preparation for business with a definite idea that he will not enter the narrow and higher technical branches of engineering. To this end, the student

should be encouraged to broaden his college course by means of fundamental studies relating to administration and management."

The Solution

Three years ago at the University of Maine—with President Boardman's approval—I introduced a course known as "General Engineering." Its freshman year varies in nowise from that of the other engineering courses which is common to all and consists of English, engineering drawing, mathematics, physics, and chemistry. In the succeeding years, as a skeleton framework, I insist upon a further study of chemistry—especially Qualitative and Quantitative Analysis—basic courses in electrical engineering, a basic course in Thermodynamics in the Mechanical Engineering Department, and Theoretic Mechanics and Structures in the Civil Engineering Department.

Students are admitted to this course at the beginning of the sophomore year on the basis of high scholastic rank and general promise. The dean of the college acts as their adviser and counselor.

If it appears that a student desires ultimately to go into administrative work, his courses are selected with that in mind; if he shows ability and the desire to go into higher design, he takes other courses. In other words, a sincere attempt is made to analyze and develop the student, and to direct him toward those studies which will best serve to train him for the type of work for which he is best fitted and has a strong desire to undertake.

You may recall that at the last meeting of the Land-Grant College Association Dean Kimball told us that

> "If . . . the engineer is to be an important figure in public affairs, he must acquire a broader technique than that which he ordinarily possesses and he must inform himself concerning a wide range of subjects of which ordinarily he knows little. Furthermore, he must acquire a wide knowledge of economic history and be able to trace the effect of economic changes over long periods of time."

While it is still true in many respects that the engineering student and educator is the pivotal point of a beam with pure science on one end and applied science at the other, with the whole superstructure resting fundamentally on science and mathematics, it is apparent to modern, progressive educators that other members are being added to the superstructure. The creations of the engineer have given rise to new and perplexing economic and sociological problems which the engineer is being called upon in greater and greater degree to solve. It is probably true that the

engineer is in a better position, because of his knowledge of the engineering problems as well as the economic and sociological and human aspects of the situation, to undertake constructive leadership in modern society than the lawyer, banker, or statesman. It is evident, therefore, that the pivotal point foundation must be broadened out and the student more thoroughly educated in humanistic and sociological studies.

I am of the opinion that scientific, mathematical, and humanitarian courses should run concurrently, as the humanitarian and sociological aspects of life are inextricably intertwined with modern scientific and engineering development.

As the scientific and mathematical studies represent a continuous evolution and progression throughout the course, so should the humanistic studies be developed in order that the student may get a comprehensive and sustained viewpoint. A student should not study economics because it is a course in economics; nor any engineering course simply because it is an engineering course. Some of the principles, so important in engineering, can be taught in any economics course. And I think you will agree that it is a very poor engineering teacher who teaches no economics in his engineering classes. In other words, prolonged and sustained application and interest must be the keynote in any subject. The student who makes a thorough study of economics will inevitably be drawn to a consideration of the historical development of nations—to their customs, their language, their art, their music, and their literature—so that many of the points of view, held by the classicist, by the leaders in the Arts colleges, and by the engineering educator, will to a large extent be harmonized.

The desirable features of a thorough training in engineering fundamentals, of a cultural and humanistic background with the development of progressive courses emphasizing the interrelationships of economic and sociological problems, can be realized in a general engineering course.

Possibly you think this too large an order for an undergraduate course. I do not. A student will not follow up all his undergraduate humanistic studies, but if he is a real student—and as I have said, at the University of Maine those taking the General Engineering Course are selected students—and he finds his stride and professional work that he likes, he will go far on his own initiative with this background.

"If we work upon marble," says Daniel Webster, "it will perish; if on brass, time will efface it; if we rear temples, they will crumple into dust; but if we work upon immortal minds, and imbue them with principles, with the just fear of God and love of our fellow-men, we engrave on those tables something that will brighten to all eternity."

And Calvin Coolidge left us this admonition:

"Our doctrine of equality and liberty, of humanity and charity, comes from our belief in the brotherhood of man through the fatherhood of God. The whole foundation of enlightened civilization, in government, in society, and in business, rests on religion. Unless our people are thoroughly instructed in its great truths they are not fitted either to understand our institutions or to provide them with adequate support. For our independent colleges and secondary schools to be neglectful of their responsibilities in this direction is to turn their graduates loose with simply an increased capacity to prey upon each other. Such a dereliction of duty would put in jeopardy the whole fabric of society. For our chartered institutions of learning to turn back to the material and neglect the spiritual would be treason, not only to the cause for which they were founded but to man and to God."

I have felt for a good many years that the teacher of science and engineering is in a strategic position to develop the character of his students and to inculcate correct principles of conduct and ethics. The very nature of the work of an engineer tends to make him inherently honest, and to develop courage, a belief in fair dealing, respect for properly constituted authority and reverence for things spiritual. He almost instinctively comes to realize with Drummond, that there is natural law in the spiritual world as well as the natural world and to glory in the fulfillment of a rich, deep, complete life of glorious achievement.

A COURSE IN THE MECHANICS OF FLUIDS *

By H. L. MASON

Assistant Professor of Mechanical Engineering, Columbia University

Every month brings fresh evidence that the engineering profession demands of its members a widening field of knowledge, a more penetrating understanding of the field, and a readiness to meet rapidly-changing conditions. Institutions offering professional training have the duty of shaping their curricula to that end. The course here described is part of a larger program, having that need in mind, which has been initiated for the Mechanical Engineering Department of the Columbia School of Engineering by its executive officer, Dr. Charles E. Lucke. Although the development of this program into a curriculum has not yet been publicly announced, its philosophy is briefly quoted:

"Major emphasis is placed upon processes and principles, with apparatus relegated to the secondary rôle of illustrating a process or principle. In mechanical engineering we may set up three major divisions of processes—mechanics of solid bodies, mechanics of fluids, and heat. For teaching purposes we find it advisable to offer in each division sequential courses of three degrees of difficulty—(*A*) introductory, (*B*) intermediate, (*C*) advanced. Courses more specifically aiming at engineering applications of group assembly type come last, in a Power Machinery group and a Process Machinery group. The general idea has grown out of experience with our Heat Transfer course, which has illustrated (*A*) since its initiation by Dr. Lucke in 1913. Based on a classification of its typical processes (*e.g.,* transfer from a condensing vapor to a heating liquid) the general physical requirements are examined, and then typical apparatus is analyzed qualitatively to see how far it fulfills the specifications. To illustrate a case, under the process class of condensing vapor to heating liquid we find apparatus with widely differing use objective: steam-jacketed kettles, boiler feedwater and fuel oil heaters, condensers for steam, refrigerants, and oil still products. In Heat Transfer an (*A*) course is a qualitative analysis, a (*B*) course deals with quantitative relations, a (*C*) course applies (*A*) and (*B*) to new problems of design or operation and investigates newly discovered concepts."

Prior to the working-out of a complete new curriculum, the opportunity arose in 1931 of trying out the major idea in another division, and offering a Mechanics of Fluids which fitted into the

* Presented at the 40th anniversary meeting, S. P. E. E., Chicago, June 26–30, 1933.

broad scheme. The course has been presented by Professor B. A. Bakhmeteff, and in its two years' development has consistently emphasized basic principles rather than specific apparatus.

Our student approaches it with a background of prior courses which have given him drill in concepts of force, mass, acceleration, work, energy, momentum, fluid pressure and its measurement, Pascal's principle, fluid velocity and its use in Bernoulli's equation, gas cycles with adiabatic and isothermal stages. The instructor, looking ahead from this plateau of achievement, sees stretching from his feet to the horizon alluring vistas: Steam Turbine Design, Fluid Meters, Wind Tunnel Testing, Turbulent Flow, Propellor Fans, Airfoil Design, Flow at Supersonic Velocities, Hydraulic Turbines, Film Lubrication, Wind Pressure, Irrotational Flow, Skin Friction, and many more. To what, out of this wealth of interest, shall he call attention? A first task is to demolish the credo, "There is but one fluid; water is its name, and water supply and water power are its profits." The battering ram is a discussion of viscosity, using engineering units. This includes its definition in absolute terms; its useful form kinematic viscosity; its dimensions; its practical measurement; its values for air, oil, water, steam; the effect of temperature. One expects oil to be much more viscous than hot water, but is amazed to find that hot air is also, in the ratio of 25 to 1.

Reynolds' experiment with a jet of color in a tube of moving water introduces the concepts of laminar flow, turbulent flow, critical velocity, and the Reynolds number as a criterion. Then the Reynolds number is developed by the logic of dynamic similarity of stream lines around bodies of differing size, as expressing the necessary proportion of inertia forces to viscous forces for bodies completely immersed and pipes completely filled. The influence of Reynolds criterion on friction losses is noted, with examination of resistance coefficients for fluids in pipes. The Froude number, in contrast, is shown to express the proportion of inertia forces to gravity forces for wave resistance at a free surface of fluid. Problems apply Reynolds numbers to relate velocity and test-model size for wind tunnel experiment; Froude numbers for towing-tank experiment.

Next, examining flow in pipes, there is developed the parabolic velocity distribution and the Poiseuille resistance law in laminar flow, the approximately uniform distribution and velocity-squared resistance for turbulent flow past rough walls. Friction loss as a function of Reynolds number is established by dimensional analysis, and experimental data offered in confirmation. Several numerical examples from power-plant practice serve to call attention to cases where flow is laminar, and to the considerable increase

in resistance loss when it is turbulent. In heat transfer work, the useful part played by turbulence, and the insulating effect of the boundary film, are described and computed. Disc friction theory and experiment are presented. Brief mention is made of the relation of flow characteristic to the silting of canals and the hydraulic selection of ore particles.

The next major topic draws parallels and contrasts in the treatment of liquids and of gases, showing that if the density change is small, or the velocity small compared to the acoustic velocity, gas flow approximately follows hydro-mechanical laws. Thus such problems as air resistance of vehicles, wind loads on buildings, and the lifting capacity of airplane wings, are simplified. For cases involving density change, where the approach must be thermodynamic, the equations of conservation of energy and of continuity are derived for gases in direct analogy with those for liquids, and it is noted that rapidity of disturbance usually makes the polytropic process adiabatic. For gas flow through a nozzle, problems from steam turbines and from refrigeration practice are treated, with computation of velocities, densities, discharge rates, acoustic velocity ratios, and suitable section areas. Cavitation losses and pitting are examined, with quantitative data from diverging pipes, ship propellor blades, hydraulic pump and turbine runners, and reciprocating pumps.

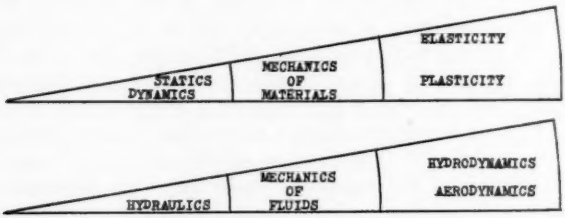
In more detailed analysis of the dynamics of fluid particles in relation to bodies completely immersed in the medium—an analysis to which research in aeronautics has so richly contributed—the concepts of hydrodynamic field, vortex, wake, disc ratio, boundary layer, surface of discontinuity, back flow, are introduced. Proceeding from Newton's flat plate to a stream-lined airship, it is shown how streamlining allows a rebuilding of the pressure head behind the body, and thus reduces considerably the form resistance. Variation of the resistance coefficient with Reynolds number, and accompanying changes from laminar to turbulent flow within the boundary layer, are noted. Problems are solved in pressures on masts and buildings, airplane struts, condenser tubes, and power saved by streamlining locomotives and automobiles. The streamlines around an airfoil, with their pressure changes, are studied to explain the mechanism of lift and drag. The polar diagram is shown as a convenient form of relating lift and drag coefficients to angle of attack. Carrying capacity and head resistance are computed for a typical airplane, also forces on a propellor, a windmill, and a rotorship. The concept of circulation is introduced, related to lift, and applied to airfoil and propellor turbine design. In the latter the connection is made with the moment of

momentum methods used for older types of guided-flow machinery, both steam and hydraulic.

The course is completed with a brief discussion of elastic phenomena in fluids and of supersonic velocities.

From this description it will be noted that the pedagogic method is a search back to fundamentals for the enunciation of a principle, followed by its application to problems taken from mechanical, civil, and aeronautical practice. The subject-matter, being widely scattered in technical literature, is presented in lecture form, with a list of reference reading. Class time is limited to 26 hours, of which several are used for quizzes. Outside of class, the student is expected to digest his notes, and then to solve the numerical problems given, and considerable credit is given on these. Although listed as required only for students in mechanical engineering, it has been elected by civil and chemical engineers as well, and several staff members have found it stimulating, with the result that the second year's registration doubled that of the first.

It is felt that other colleges will be interested in this attempt to accomplish for fluid mechanics a wholesome unification and sound arrangement of subject matter. In rigid-body mechanics, such an organization is almost an international standard. There the student's widening view may be diagrammed by a sector of knowledge, beginning with Statics-Dynamics, and extending through Mechanics of Materials to Elasticity-Plasticity. Note that



his attention is directed in turn to: (*A*) treatment of matter in the large—an overall view, (*B*) examination of internal mechanism—a detailed view, (*C*) formulation of precise all-embracing laws—an integrating view. A similar sector of knowledge for fluids might carry titles: Hydraulics, Mechanics of Fluids, Hydrodynamics-Aerodynamics. Regardless of title, however, the subject-matter outlined here has been forged under the impact of 1900–1933 research into a tool which the engineer finds increasingly useful. It is believed that Mechanics of Fluids will eventually take its place beside Mechanics of Materials in our leading engineering colleges.

SUMMARY OF STATUS AND TRENDS OF MINING AND METALLURGICAL CURRICULA *

By W. B. PLANK

Head, Department of Mining Engineering, Lafayette College

In order to obtain an accurate picture of the work being done by the Mining and Metallurgical schools, data on enrollment, course content, graduation requirements, and the employment situation for graduates were collected by the writer by means of a questionnaire in May, 1933, from 49 schools in the United States and 4 in Canada.

These data are more detailed than those published by the United States Office of Education and it is felt that they should be of interest to those engaged in education for the mineral industry. Especially since the mineral industry is the first to feel the effects of business changes, information about the training and supply of its young engineers is always pertinent.

Acknowledgment is made to the administrative officers who supplied the information about their respective institutions and to Professor H. P. Hammond, Director of the S. P. E. E. Summer School, for his assistance in drafting the questionnaire and his helpful suggestions.

LIST OF INSTITUTIONS GRANTING DEGREES IN MINERAL TECHNOLOGY—1933

UNITED STATES

1. University of Alabama
2. University of Arizona
3. Alfred University
4. University of California
5. California Institute of Technology
6. Carnegie Institute of Technology
7. Case School of Applied Science
8. University of Cincinnati
9. Colorado School of Mines
10. Columbia University
11. Harvard University

* An address delivered at the Mining and Metallurgical Session of the Summer School for Engineering Teachers, University of Wisconsin, July 6, 1933.

12. University of Idaho
13. University of Illinois
14. Iowa State College
15. Johns Hopkins University
16. University of Kansas
17. University of Kentucky
18. Lafayette College
19. Lehigh University
20. Massachusetts Institute of Technology
21. Michigan College of Mines and Technology
22. University of Minnesota
23. University of Missouri
24. Montana School of Mines
25. University of Nevada
26. New Mexico School of Mines
27. North Carolina State College
28. University of North Dakota
29. Ohio State University
30. University of Oklahoma
31. Oregon State Agricultural College
32. Pennsylvania State College
33. University of Pittsburgh
34. Princeton University
35. Rutgers University
36. South Dakota School of Mines
37. University of Southern California
38. Stanford University
39. University of Texas
40. Agricultural and Mechanical College of Texas
41. University of Tulsa
42. University of Utah
43. Virginia Polytechnic Institute
44. State College of Washington
45. University of Washington
46. West Virginia University
47. University of Wisconsin
48. University of Wyoming
49. Yale University

CANADA

1. University of British Columbia
2. McGill University
3. Novia Scotia Technical College
4. University of Toronto

Enrollment in Mining and Metallurgical Schools for 1932–33

The 49 United States schools reported four-year undergraduates in all branches of mineral technology totalling 4025, and 418 graduate students, making a grand total of 4443. In the Canadian schools there were 136 four-year undergraduates, and 16 graduates, or a grand total of 152. There were enrolled as Seniors a number of men who were not candidates for bachelor degrees, totalling 135 in the United States schools and 11 in the Canadian schools.

The distribution by classes is shown in Table I.

TABLE I

Enrollment by Classes, 1932–33

	U. S.	Canada
Freshmen	1105	30
Sophomores	1058	22
Juniors	1021	47
Seniors	841	37
Total Undergraduates	4025	136
Graduate Students	418	16
Grand Total	4443	152
Candidates for Bachelor Degrees	706	26

Differentiation of Mineral Technology Courses

In all, nineteen different mineral technology courses, or options, are offered by our Mining schools, leading to almost as many different bachelor degrees. These are:

Mining Engineering
Coal Mining
Metal Mining
General Mining
Mining Administration
Mining and Metallurgy

Metallurgical Engineering
Metallurgy

Petroleum Engineering
Petroleum Refining
Petroleum Geology
Petroleum and Natural Gas

Ceramic Engineering
Ceramics

Geological Engineering
Mining Geology
Economic Geology
Geophysics

Fuel Technology

It is apparent that many of the courses within the groups are so similar in content and objective that there seems to be little justification for this diversity in names. It is, perhaps, because of different traditions at the various schools, but the writer wonders whether it may not be because we mineral technology educators have been trying to educate our young men in the colleges for separate branches of the mineral industry rather than for the "mining engineering profession." In other words, are we not teaching special practices in these branches believing that thereby our graduates may at once find responsible positions in these respective fields? When we do this, are we fully aware of the rapid changes taking place today in practice—changes that more often than not make such practice obsolete by the time the young men reach the field?

It is a moot question as to how far specialization within the field of mineral technology should be carried in college, but the writer believes that we ought to examine this matter closely and try at least to arrive at some semblance of uniformity and simplification of names and objectives.

For the purpose of this report these 19 courses are grouped into 6 main divisions and given the general name of the major subject or branch of mineral technology they respectively represent. These are shown in Table II with the enrollment in each group.

TABLE II

ENROLLMENT BY COURSES, 1932–33, UNITED STATES.

Subject	Fresh.	Soph.	Jrs.	Srs.	Total Under-Grad.	Grad. Stud.	Grand Total	Cand's Bach. Deg.
Mining	374	349	331	257	1311	82	1393	224
Metallurgy	253	291	312	255	1111	177	1288	207
Pet. & N. G.	187	170	181	174	712	14	726	152
Ceramics	182	127	83	85	477	45	522	66
Geology	90	101	96	60	347	40	387	48
Fuel Tech.	19	20	18	10	67		67	9
Grad. Students, Not Differentiated						60	60	
Totals	1105	1058	1021	841	4025	418	4443	706

TABLE III

GRADUATE STUDENTS IN MINERAL TECHNOLOGY, UNITED STATES.

Subject	1928–29	1929–30	1930–31	1931–32	1932–33
Mining	31	32	45	58	82
Metallurgy	63	88	87	137	177
Pet. & Natural Gas	2	13	37	23	14
Ceramics	22	14	34	35	45
Geology	14	19	20	27	40
Not Differentiated	36	31	40	70	60
Totals	168	197	263	350	418

NON-TECHNICAL SUBJECTS IN CURRICULA

The number of credit hours of non-technical subjects required runs from 9 to 34, the average being about 18 hours, or 6 three-hour courses.

Thirteen schools report that their policy is toward more non-technical subjects, and fifteen schools announce no change in their policy. Some of this latter group already require more than the average.

REQUIREMENTS FOR THE BACHELOR DEGREE

There is a wide range in the total number of credit hours required for the bachelor's degree. Some schools require as few as 136 and one as many as 180 hours, the median being about 150. This wide variation indicates lack of uniformity in recording credit hours and an exact comparison cannot be made without a closer examination than this questionnaire permitted. In this respect, one large school in the East and another in the West are on a graduate basis, granting only the graduate degrees.

SUMMER WORK

Some of the answers to this question indicated that it was partially misunderstood. The other answers, however, showed that a general requirement for a bachelor degree is one, or two, summer courses, consisting of field work, either on the college campus or elsewhere, or both.

EMPLOYMENT STATISTICS

Only an estimate was asked of the employment situation of the graduates of 1932 and the prospects for those of 1933. Employment was intended to mean gainful occupation or study.

For the 1932 group, the replies showed a range of 25 per cent to 100 per cent employed. The average was better than 50 per cent employed.

12	schools	reported	100	per	cent	employed
3	"	"	90	"	"	"
3	"	"	80	"	"	"
3	"	"	60	"	"	"
7	"	"	50	"	"	"
4	"	"	25	"	"	"

1 large school reported 10 per cent

This shows a favorable situation for the mining and metallurgical engineers as compared with other engineers. M. M. Boring's investigation showed that, out of 10,000 graduates in 1932 from 33 engineering schools, only 34.2 per cent were employed.

To the question as to the prospects of employment for the 1933 group of mineral technology graduates, the replies ranged from very good to very poor. The majority of schools reported more than half of their men placed with three large schools reporting all of their men placed.

Two of the four Canadian schools reported all of their men placed in 1932. One school had no graduates in 1932 nor in 1933. One school reported all of its graduates placed in 1933 and another, half of its graduates.

Conclusion

The following conclusions are presented as a possible basis of discussion. They seem to be indicated by all recent studies of mineral technology education, and the writer believes that they are good objectives:

A. There should be a greater recognition on the part of our mineral technology teachers of the rapid changes in the technology of mining, metallurgy, and geology, with a consequent greater emphasis on principles and less on practice.

B. The majority of mining schools should have a basic course with a limited number of options in the Junior and Senior years, such as mining, metallurgy, oil and gas, and ceramics. Further specialization should be done in a graduate school.

C. The number of bachelor degrees should be limited to one or two, regardless of the option taken. This would tend to discourage over-specialization.

D. Provision should be made in all curricula for the better development of the two types of men: the managerial or administrative type and the scientific or technical type.

E. A definite beginning toward preparing the student for his professional career should be made while he is still in College, and this should be continued after graduation through

closer coöperation with the mineral industry. A recognition of the need for this is seen in the work of the newly formed Engineers' Council for Professional Development.

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VITAL ELEMENTS IN THE TRAINING OF MINING AND METALLURGICAL ENGINEERS *

By FRANCIS A. THOMSON, *President*, Montana School of Mines

In discussing the interesting topic upon which I have been asked to speak I want to begin by emphasizing the distinction between training and education, for in spite of the circus posters about educated dogs and ponies, the prime distinction between animals and men is that animals can be trained but not educated, whereas human beings can be both educated and trained. This distinction suggests a fundamental question toward the recognition of which we have been groping but have not exactly enunciated, namely, how much of the preparation of mining and metallurgical engineers, as indeed of all other engineers, should be "*training*" and how much of it should be "*education.*" True, the line of demarcation may not be one which can be sharply drawn, or to put it more exactly, there is a twilight zone between the two; nevertheless, at each end of the scale there is no trouble in differentiating between certain types of preparation. For example, years ago in a very few weeks I taught an intelligent Chinese Coolie to do routine fire-assaying, but when a strange ore was encountered, my Chinaboy was "stumped," because he had been *trained* to assay one type of ore instead of being *educated* in pyro-metallurgy.

So also with many of the "tool subjects" which we teach in college. Almost any student with the faintest glimmerings of intelligence can be "trained" to be a fair draftsman, provided there are not too many complicated intersections to deal with, but I have not infrequently observed that there is no necessary correlation between ability to make a pretty drawing and ability to think clearly. Indeed, I think it fair to say that draftsmen may be *trained* but designers must be *educated.*

It does not require mental ability of a high order to be able to learn which end of a telescope should be pointed at the object and which at the eye, nor to "spot" the intersection of the cross-hairs on a nail set in a stake, and then to read the horizontal and vertical angles and set them down in a book especially ruled for that purpose. I believe I could have taught this to my Chinaboy as easily as I taught him the routine determination of gold and silver.

* An address delivered at the Mining and Metallurgical Session of the Summer School for Engineering Teachers, University of Wisconsin, July 13, 1933.

Obviously, however, the interpretation of the result of a transit survey, the choice between this or that possible location, or the accommodation of the structure to the terrain revealed by surveying, calls for engineering ability of a high order, which can be developed by education but not by training alone.

Other illustrations will, of course, occur to you and nothing is further from my intention than to launch into a discussion of curricula although it might be an interesting thing for each of us to study his own curriculum and list those subjects which are of training value only, those which have training value and educational value, and those which are educational only, with a view to maintaining an adequate balance between them.

Now to revert back to our topic "Vital Elements in the Training of Mining and Metallurgical Engineers" will you pardon me if I say that I'm inclined to think that in the long run—and remember the long run is hard on short-winded people—in the long run, those elements are the most vital, in which the "training," in the sense in which I have used the word training, is subordinated and fundamental principles of general application are emphasized.

A study of the earlier curricula will show an overwhelming emphasis on drafting, surveying, and assaying all taught from the point of view of training. To-day the emphasis is shifting and some of the leaders in our field are questioning the validity of certain of these subjects hitherto considered indispensable. At the same time we must recognize that many of our students are distinctly "thing-minded," and that their interest will be keener and better sustained if they have some opportunity to use their hands in what the psychologists call motor-response.

Let us get back to *"vital elements."* What are they? Unanimity of view is probably neither possible nor desirable, and only in the generalities is there likely to be agreement. However, to begin with, we cannot do better than to remind ourselves once more of James A. Garfield's dictum concerning the parson-president of the Williams College of his day, "A university consists of Mark Hopkins at one end of a log and a student at the other."

Here we have the irreducible minimum for mining and metallurgy as for every other field of education. To paraphrase the 13th Chapter of First Corinthians, "Now abideth, teacher, student, and facilities and the least of these is facilities."

Of course, we are all proud of new laboratories and new equipment when we get them; indeed most of us have spent many weary years waiting for the fruit of the budget-tree to make such things possible. However, I am not sure that our teaching was as greatly improved as we had fondly imagined it would be when we were

finally able to purchase the new lot of instruments we had waited for so long. Nevertheless, a qualification is needed here, and I must remind you that I am speaking of undergraduate instruction and not of graduate instruction or research, although even here we may have been suffering from an "apparatus complex," as we are apt to discover in the lean years ahead of us. For I anticipate a hysteresis period in which the 'magnetism' of education will lag behind the 'current' of economic recovery.

Manifestly, however, in Garfield's trilogy as in the topic assigned to me, the most vital element is the teacher.

Volumes have been written as to the qualifications of the good teacher; volumes remain to be written. Outside of the fact that he must be intelligent—brains are useful anywhere, even in the teaching profession—the good teacher conforms to no particular type. Some are apparently so industrious that they do all the work themselves and thus, like the pigeons, feed their students predigested food and are failures. Others are so lazy they make the students do all the work and thus they become good teachers by reason of their delinquency. Some great teachers are stern disciplinarians and their students learn to do their work promptly and precisely; others are lax in their demands but somehow manage to kindle the spark of interest that glows and even burns brightly long after the carefully prepared notes and problems so meticulously done for the disciplinarian have been forgotten. Some teachers have their work so carefully prepared and their lectures so logically arranged that the bright student can always see what is coming for fifteen or twenty minutes ahead and so loses interest. Others are unsystematic but brilliant and the interest is sustained. As I wrote to a colleague of mine some time ago, "It may seem cruel to say it, but I sometimes think the best thing that could happen to you would be for the carefully prepared and meticulously written notes from which you have been lecturing for the last ten years to be suddenly destroyed. I say this because I think it would cause you to re-vitalize your teaching."

I need hardly say that I am making no argument for laziness, laxness, or inadequate preparation, but I am inclined to be wary of any generalizations as to what constitutes the good teacher. (Perhaps it was Voltaire who said "all generalizations are unsafe including *this one.*")

Furthermore, I want to say to those of us who have spent a good part of our lives teaching small groups of young men some of the subjects of our own craft, that we do not know what teaching problems are. Our students have usually been juniors and seniors, the loafers have been weeded out and the professional interest is fairly well developed. Compare our problem with that

of the instructor in freshman mathematics, or English, or history, or language, and it is at once evident that our "lines have fallen in pleasant places"—and I am inclined to think that if we are half as good teachers as these drill-masters must necessarily be, we should do twice as good a job, because for us in large measure the problem of interest and of pride-in-work on the part of the student has been so largely solved.

And this brings us to the student as the other vital factor in the situation. He is the clay with which we as the potters must work. Plastic? Oh yes, very. But we are not the only forces that are at work in the ceramics of education, and perhaps this is fortunate. I remember that in "Joan and Peter" H. G. Wells makes Peter after a year or two at Cambridge say, "It doesn't matter so much what a fellow studies, if he has only met enough fellows who have studied something else," and although one might reply that the trouble with Peter in an American college is likely to be that he will meet too many fellows who never did and never will really study anything, nevertheless, mayhap if Peter has the right stuff in him he will learn some of the things to be avoided.

And the use of that phrase 'the right stuff' reminds me again of the clay analogy. For even as our friend and fellow mineral-industry-educator, the ceramist, has clays of vastly different qualities to deal with, so we, in our work as teachers find the widest range of ability and of possible attainment in our students. Our Stanford friends, like the Jews, most naturally took great pride in the fact that "one of their boys had made it" when Herbert Hoover was elected president and they did a bit of pardonable crowing about it. Harvard, on the other hand, with a long line of sons who have filled the presidency, perhaps from the complacency of age and of assured position, accepts such a thing as a matter of course and indeed almost of right, but under it all Harvard probably realizes that both the Roosevelt boys would almost certainly have become president if Theodore had gone to Yale and Franklin to Princeton or Columbia, or possibly even to Podunk.

We as teachers can probably make pretty fair assayers, transitmen, and draftsmen out of the faithful plodding type of students, but most of the great leaders of our profession would probably have been leaders in large measure regardless of the teachers under whom they were educated. Does this then reduce us as teachers to mere trainers of men for routine jobs? I don't think so. Between the extremes of the mere faithful plodders on the one hand, and the men of surpassing ability on the other, comes the large middle group of bright ambitious youths many of whom —circumstances permitting—will go as far as we are capable of preparing and stimulating them to go. It is this group that

will most vitally profit by *vital elements* in our teaching. For this group then, how may we most thoroughly vitalize the training and the education we endeavor to give them?

Certainly not by curricula, nor, with the exception of certain major emphases, by improving the curriculum. For as I wrote to a fellow alumnus who desired me to criticize the curricula at my own Alma Mater some months ago.

> In response to your circular letter of December 29 let me say that I should hesitate to make any specific suggestions in regard to modification of the curriculum at the School of Mines. Possibly this hesitation arises from the fact that I have been engaged in the making of mining school curricula for over twenty years and that I realize more fully than anyone not familiar with the subject, the difficulty of making a satisfactory curriculum for an institution with which one is in intimate daily contact, and this leads me to be rather doubtful of the value of suggestions however well meant they may be with respect to the curriculum in one's alma mater. Indeed I have come to the conclusion that the details of curricula are really of less importance than the soundness of the teachers and the teaching. In other words, I believe an institution in which the curriculum may be open to a good deal of criticism, but which has a high-grade faculty and high standards of scholarship, will turn out better men than one in which the curriculum is ideal but in which the standards are low and the teaching is poorly done.

Furthermore, I have taught too long to have illusion as to curriculum making. All curricula are compromises between desire to progress, ineradicable subject prejudice, department prestige, and well intrenched tradition, and I have also seen too much to believe that any particular subject is essential to a student's intellectual or professional salvation. Twelve years ago I had a call for a man to go to one of the western oil fields to keep track of well-logs and do other similar minor engineering work. The only available man was a most competent and intelligent fellow who had just completed a year of graduate work in flotation based upon four years of excellent undergraduate preparation in chemistry but with never a course in the geology of petroleum or the geology of anything else. To-day that man is a recognized authority in the geology of the field to which I sent him. Does this mean that the proper training for petroleum geologists is chemistry followed by graduate work in flotation? Not at all. But it does mean that given a good intelligence and a keenly acquisitive mind, with a sound education in one of the sciences which has taught him first how to study and second to base conclusion upon ascertainable data, this man by keen observation, by self-study, and by ability to acquire information from others, was able to master a technology in which he had absolutely no specific preparation. No doubt all of you can recall from your own experience similar instances; they are by no means uncommon.

I am disposed to think this represents one of the *vital elements*

we are searching for, namely, a type of preparation which will teach the student how to study, which will teach him how to collect data, how to observe and how to record, and above all how to synthesize the data when collected; in short, how to do a good job.

Indeed, I am disposed to set up the development of analytical and synthetical ability as another *vital element* or factor in the student's preparation for professional practice.

I know it is commonly considered that the one and only way to develop analytical ability is through mathematical training—and here I use the word 'training' most advisedly for I find myself beginning to wonder whether we have not been teaching our students a series of mathematical tricks and 'stunts' and assuming that thereby we were teaching them to think analytically in general.

Again I turn to my letter file for an illustration of what I mean. In a lengthy discussion addressed to Dr. D. A. Lyon, copies of which were sent to a number of us, Professor T. T. Read of Columbia referred to the fact that students are apt to regard non-mathematical discussion as "drooling" and said:

> The students do have that attitude toward expository lectures and they are quite wrong. It develops out of our placing too much emphasis on the mathematical solution of specific problems, which gets them to thinking only in those terms. As a result not 2 out of 10 young engineers can participate in a general discussion of broad problems on the basis of seeing just what is involved and being able to evaluate the different factors. You may say that is because they are too young to do it, but my argument is they have the wrong attitude toward it, just as many of them have the wrong attitude toward the necessity for being able to state their case in clear understandable English. There is no difficulty in getting people to find the solution of a specific problem that is clearly stated, any more than it is difficult to find designers for a plant, once you have decided what kind of a plant you ought to have. Mining engineers, more than any other kind of engineers, work in a field where the problem is to decide what you ought to do, rather than designing the doing of it. Nobody likes to be worried with trying to decide what to do, they delight in doing something if somebody else will take the responsibility for the decision. Instead of giving our students too little in the way of specific tasks, I believe we are doing them an injury in yielding too much to their natural desire to have only specific tasks assigned them.

In reply to this portion of Dr. Read's letter I wrote as follows:

> My attention has particularly been focused recently on that portion of your letter in which you discuss the subject of "drooling." I had a recent experience which illustrates this thing exactly. I have been having my seniors read Graton's articles in the *Transactions* and *Mining Congress Journal* on mine taxation, depletion allowance, and so forth, together with other cognate material. The whole conception is a novel one to them and it usually takes several weeks to get it through their heads. Then, while I was away for a week I had one of our mathematics people give a couple of lectures on mathematics of investment leading up, of course, to Hoskold's formula. Shortly after my return I gave a little quiz of one hour duration. Three questions dealt with the

general principles of mine valuation, mine taxation, and depletion allowance, and one question dealt specifically with the application of Hoskold's formula. Every one of the eighteen men in the class handled the question which involved the formula correctly. The answers to the three questions, which involved thinking without a formula, were not handled nearly so well. This illustrates exactly the point you make. When the members of the class came to the formula question, it is quite evident they said to themselves, "Ha ha! here is something we know how to do. We have been working with formulæ for three and one half years in college and four years in high school—this is where we shine." Our professor of Physics tells me that when he asks his students to state a physical law they will write the formula and will think they have stated the law.

So, if what you and Dr. Lyon referred to as "drooling" is the remedy for this attitude, I am in favor of "drooling" as thus defined plus required reading of good tough material.

In much the same way have we not believed that because a student had learned to integrate in calculus, he had also learned the art of summation in general, when actually nothing could be further from the truth? Indeed I am satisfied that the ability to synthesize, to gather together bodies of more or less unrelated facts from various sources and then to relate them to a specific situation upon which they have a bearing is a rarer quality than is analytical ability. Perhaps this is another illustration of the well known fact that it is easier to tear down than to build up.

A few years ago I had occasion to serve on a civic committee appointed to see what might be done to abate a local industrial nuisance. We called in a college-*trained* man, familiar with this particular technology, to advise us. The man was a perfect encyclopedia of information on the subject, but like the encyclopedia, he was utterly incapable of applying his wealth of information to a solution of the problem before our committee. His facts were all in water-tight compartments and, so far as he was concerned, they had never been related into a comprehensive logical picture of the whole, and this is by no means a rare experience.

Probably the work in design which the civils and mechanicals especially are called upon to do is the best illustration of synthesis we have, and possibly we should be thinking more along these lines for the miners and the metallurgists.

Closely akin to synthesis and design in the broader sense of that term, is *imagination* which I would list as the third ingredient in the preparation of the future engineer. I had the privilege while at Washington in May of dining with a gentleman who has made a conspicuous success in the field of mechanical engineering and who interestingly enough was trained in Liberal Arts (Curriculum fanatics please note!). This gentleman wanted to know why so few of the hundreds of engineering graduates whom he has employed show any imaginative ability. My host appealed to

me as one interested in engineering education to know if anything was being done or could be done to teach imagination to engineering students. Of course my first answer was that imagination like ability in music and the arts is in large measure an inherent quality, which might be improved by exercise but which could never be implanted where it did not initially exist. My friend admitted this but said he thought the percentage of the imaginative type was smaller among engineering graduates than among other normal groups. I am inclined to agree with this wholly tentative conclusion, the soundness of which it would be difficult to test, and if there is any truth whatever in it, then I submit, as a possible explanation, the hypothesis that the more imaginative type of high school boy is inclined to shy away from what he had heard in high school of the rigor and grind of an engineering course. Possibly, if the Liberal Arts Colleges keep on tightening up with their comprehensive examinations and various other plans for making their students work, then engineering, law, and medicine will not look so tough by comparison.

Returning to imagination again for a moment, a legal friend of mine in Chicago with whom I discussed this matter recently said, "I'd like to see what would happen if, in lieu of your stereotyped freshman curriculum in the engineering colleges, you should give your freshmen a year of literature, poetry, music, art appreciation, history, and any other subjects which could never possibly be of any subsequent professional value." Of course, the reply was obvious, the student would still have his freshman engineering work to do; whether he would have a better developed imagination I'm not sure, but I'm willing to admit that he would probably be a better and a happier engineer.

But I leave as a problem for your solution the question of engineering students and imagination. I know of but two courses that specifically require imagination—one is descriptive geometry with its need for space visualization—the other is design of any kind which affords scope for original ideas. Surely our friends the architects must have given some consideration to imagination as a feature of their system of professional education.

Perhaps our own present system makes too few demands upon the imaginative quality, which, even though it be an inherent trait, can probably become atrophied from lack of use, or developed by wise stimulation.

The fourth vital element which we would all like to give to our students in measurable degree is judgment plus character—that peculiar combination of intelligence and experience—that quality which, under the head of wisdom, Robert Bridges described as "masterful administration of the unforeseen." But this would

be putting old heads on young shoulders, something we had better avoid even attempting.

Finally we come to those vital personal qualities, which quite as much as intellect make for success or failure in the life of any professional man. And here we deal with subtleties which in the main are better taught by example than by precept, although a skillful teacher in whom students have complete confidence may, when alone with a student, be perfectly frank in suggestions as to personal habits, speech, and behavior, without the slightest offence. In twenty-five years of teaching I recall but one instance where a suggestion of this kind was resented—this was in the case of a senior during my first year in an institution to which I had just transferred. If I had had him from a freshman there would have been no question about it.

Closely allied to this desideratum and as a part of preparing the student to orient himself to the society in which he must live and thus make him a better citizen, is a certain amount of time spent in the study of the humanities and on what is generally for lack of a better term called the social sciences, with some emphasis on economics. There may be some question as to whether the man trained in mining may not wind up in metallurgy or vice versa; there may be some question as to whether twenty years after graduation he would know what to do with an integral sign if he met one; but there can be no question that he will be associated with other people and will either be handled by them or will have to handle them himself. Furthermore, he will have public questions to deal with if he amounts to anything whatever and the sooner he becomes socially minded the better for him and for society.

Summarizing then, it is obvious that the vital elements of the situation as a whole are the teacher, the student, and the facilities, and that of these, facilities are the least important.

Granted this axiom, then the vital elements which we should strive for in the preparation of the student himself are:

(1) The development of ability to study, to collect data accurately, and to record it properly.
(2) The development of ability to analyze and particularly to synthesize.
(3) The development of imagination and originality.
(4) The development of judgment and wisdom.
(5) The development of generally acceptable personal qualities, and of orientation to the world about him.

The conclusion is reached that details of curriculum and of subject-matter, although of great importance, are less significant than we are apt to think. I suggest that unless, through his completion of a given curriculum, the student does in reasonable

measure attain some mastery of each of the five points enumerated, the curriculum has harmed him more than it has aided him.

I submit these five items to you as "the Vital Elements in the *Education* of Mining and Metallurgical Engineers," in the belief that without them we are in danger of training artisans in the field of engineering, instead of educating future professional gentlemen.

It may be argued that all of this points to the six-year course. which it does, but there are seriously practical difficulties in the way, and in any event, that, as Kipling says, "is another story."

COMMENT—S. P. E. E.

By R. S. SWINTON,

Georgia School of Technology

The JOURNAL OF ENGINEERING EDUCATION for March, 1933, carries several articles which attract one interested in the field of Engineering Mechanics. First there is the article "Things That Are Commonly Wrong in Textbooks on Machine Design" by Professor W. Trinks. The stresses in bolts, nuts and key ways as they occur in mechanical engineering compare with the knowledge of stress in riveted joints encountered by the structural designer. Both point to a lack of recognition of the behavior of metals in the plastic ranges. Indeed, many texts scarcely recognize the plastic condition, and problems in that field are treated as if outside the pale of science.

In some schools the civil engineering division is the father of all the branches and the strongest fundamental work is done by the structural men. In other schools the field of mechanics is covered by the mathematics or physics staff, while elsewhere metallurgy has expanded into that field. It would seem to make little difference whether a student was required to take a course in machine design or structural design so long as that department in his particular school was best equipped to make clear the principles and application of engineering.

It is right at this point where the mathematics, physics and mechanics departments should offer a service. Such books as Mach's "Science of Mechanics" and Todhunter and Pearson's monumental "History of Elasticity and Strength of Materials" show that it takes from fifty to one hundred years for a pure mathematical theory to become engineering practice. This cannot possibly be tolerated under modern conditions and a man capable of understanding the works of the best scientists and interpreting them to the designer is invaluable.

To this end such courses as described by Dr. F. L. Everett in "An Experimental Course in Mechanics of Materials" with adequate illustrative material, lectures and computation periods should go a long way in clarifying a field now regarded as obscure. The purpose of such a course must be distinguished from that of "Testing Materials" in which a familiarity with standard testing procedure is the object and the illustration of principles incidental.

An advantage in the introduction of the course is the relatively inexpensive equipment required for most illustrations. Large testing machines are non-essential. A breadth of engineering experience on the part of the teacher greatly enriches the course. Much background can be gained from reading up on the subjects in such books as Todhunter and Pearson, but modern books and papers are required to keep in touch with recent developments.

REPORT OF THE COMMITTEE ON TECHNICAL INSTITUTES *

We shall use only a few minutes in bringing up to date certain data which appeared in "A Study of Technical Institutes," published by the Society in 1929. Your Committee on Technical Institutes was appointed too recently to permit a formal or comprehensive report at this time; therefore, the Committee requested permission from the officers of the Society to present, at this meeting, brief items indicating trends perhaps, or a progress report.

Recent data from fourteen representative technical institutes indicate, during the five-year period since 1929: (1) that the applicants for admission to the institutes are prepared better scholastically, (2) that the total enrollment in fourteen representative technical institutes dropped from 8,886 in 1929 to 7,656 in 1933, or a decrease of 13.9 per cent compared to 14.0 per cent in the engineering colleges during the same period, (3) that three of the fourteen technical institutes charge no tuition, five have not raised tuition, while six have raised tuition an average of 27.4 per cent, (4) that approximately 55 per cent of the 1932 technical institute graduates are in permanent positions, 12 per cent are in makeshift positions, 26 per cent are employed, and 7 per cent are continuing formal education, (5) that one technical institute has not reduced faculty salaries since the study in 1929, while thirteen have reduced such salaries an average of 20 per cent, (6) that six institutes have increased teaching loads in hours, while eight have not increased teaching loads expressing a fear that such action would endanger quality of instruction, (7) that six institutes have increased teaching loads in size of classes, while eight have made no increase in this direction, (8) that in connection with the S. P. E. E. continuing activities in the technical institute area of education, an area closely related to the usual four-year engineering area, one institute suggested that such activities should be handled by some orgnization having a keener interest in the development and success of the technical institutes, three were noncommital on this question, and eleven recommended that the Society continue or enlarge its activities in this area of education, and at the same time suggested the possibility of a program during the annual meeting of the Society.

Your Committee, therefore, recommends: (1) that the Society

* Presented at the 40th Anniversary Meeting S. P. E. E., Chicago, Ill., June 30, 1933.

continue activities in this area of education, (2) that the present Committee on Technical Institutes, without a change in the present personnel, be continued for another year with the exception that two additional members be added to said Committee, (3) that since this is a committee on technical institutes, the technical institutes be represented in its personnel, (4) and, that since the "terminal" courses of many junior colleges, in spirit at least, fall within the area of technical institute education, the Chairman of the Society's Committee on Junior Colleges be named as one of the two additional members of the Committee on Technical institutes, thus making for better coördination.

Respectfully submitted,

R. E. DAVIS, University of California,
W. E. WICKENDEN, Case School of Applied Science,
R. H. SPAHR (Chairman), General Motors Institute.

Therefore, Mr. President, your Committee on Technical Institutes desires to make a motion at this time, if that may be in order, that the foregoing recommendations be adopted. The motion was passed.

The T-SQUARE PAGE

DEVOTED TO THE INTERESTS OF THE DIVISION OF ENGINEERING DRAWING

FREDERIC G. HIGBEE, EDITOR

The Engineering Report: "A report is the orderly communication of useful information or counsel required by some one for a specified use, to be made in the form best fitted to satisfy all the requirements of service to which the report will be put and with such interpretive comment as is needed to make it intelligible to the reader.

This definition regards the report not so much as an academic problem in writing as an engineering problem in communication. It involves not only a mastery and ordering of the ideas to be presented, but a keen insight into the needs of the reader to whom the ideas are to be communicated and a sympathetic estimate of the difficulty he may have in grasping them."—*J. Raleigh Nelson.*

* * *

"In illustrating an engineering report the writer will have to consider:

(1) To whom the report is addressed.
(2) What to illustrate.
(3) The kind of illustrations to use.
(4) The final form of the illustrations.
(5) The technique." —*Thos. Ewing French.*

* * *

"And then, in addition to the text, many of these articles must be illustrated. Here again the young engineer must learn to combine artistry with the technical, mechanical drawing with which he is familiar. Illustrations must not only be accurate enough to pass technical inspection but they must also be clarified and humanized so that the non-technical laymen can understand them and can interpret them in conjunction with the written text. Sometimes this requires perspectives, sometimes phantom views, sometimes combinations of photographs and diagrams—whatever the requirements, the author should be able to supervise the proper illustration of his writing."—*Ralph Leavenworth.*

The responsibility of Engineering Drawing departments for a considerable share of the training of engineering students in this important feature of engineering work may be further emphasized by a quotation from the Chinese: "One picture is worth ten thousand words."

SECTIONS AND BRANCHES

The first meeting of the **Georgia Tech Section** was held on November 3, at which time the officers were elected and the year's program was outlined. Professor Montgomery Knight succeeded Professor H. W. Mason as Chairman. Professor N. C. Ebaugh succeeded Professor R. S. King as Secretary.

A survey committee of last year was continued over and will carry on their work throughout this year. This committee consists of H. W. Mason, Chairman, M. Knight, D. P. Savant and R. L. Sweigert. This committee is sponsored by the Local Section of the S. P. E. E. and proposes to investigate all phases of the school's activities.

It is expected that the monthly meetings of the branch will consist chiefly of discussion concerning the progress of the survey committee.

We are glad to be able to report that our enrollment is only about 20 per cent less than that of last year. This drop is due chiefly to the removal of the School of Commerce from this campus to the University of Georgia at Athens, Ga., so that the engineering enrollment is practically the same.

NEWTON C. EBAUGH,
Secretary.

Kansas-Nebraska Section.—The Kansas University group welcomed the visitors on Friday, October 27, 1933 at a 6:30 o'clock dinner at the University Club, 1433 Ohio Street. This afforded an excellent opportunity for introductions and the renewal of acquaintances.

At 8:15 P.M. the first session was called to order in the Engineering Auditorium by the president, Prof. R. G. Kloeffler, K. S. C.

Chancellor Lindley of Kansas University welcomed the visitors to Kansas University. Prof. L. E. Conrad, K. S. C., gave a short report of the Annual Meeting of the S. P. E. E. which was held in Chicago. Dean R. A. Seaton, K. S. C., discussed the work of "The Engineers' Council for Professional Development."

At 9:00 P.M. the official business of the meeting was taken up. The minutes of the last meeting, as reported by Prof. L. V. White, K. S. C., were read and approved. A letter, written by Prof. Charles H. Fulton, Chairman of the Missouri Section of S. P. E. E. to the Kansas-Nebraska Section of S. P. E. E. was read. In that letter, Professor Fulton invited the Kansas-Nebraska S. P. E. E.

members to attend the Missouri S. P. E. E. meeting to be held in Columbia, Mo., November 3 and 4, 1933. Previous to this meeting, Chairman Kloeffler had appointed a nominating committee. The members were

Professors F. A. Russell, K. U., Chairman,
C. E. Pearce, K. S. C.,
O. E. Edison, U. of N.

The following men were nominated as officers for the coming year.

For President, Prof. E. E. Brackett, U. of N.,
Secretary, Prof. A. H. Sluss, K. U.,
Chairman of Program Committee, Prof. M. W. Furr, K. S. C.

The report of the nominating committee was adopted and these men declared elected for the ensuing year. Prof. C. E. Pearce, K. S. C., invited the Kansas-Nebraska section of S. P. E. E. and the Iowa State College faculty members to meet in Manhattan, Kansas, next year. The invitation was officially accepted. Chairman Kloeffler called to the attention of the members that Prof. G. R. Chatburn, U. of N., the first president of the Kansas-Nebraska Section of S. P. E. E. was not present. It was then moved by Dean R. A. Seaton, K. S. C., seconded by Dean G. C. Shaad, K. U., and carried that the Secretary inform Prof. Chatburn that the Section members were sorry he could not be present. The Secretary was also instructed to send Prof. Chatburn greetings and good wishes. These instructions were carried out that evening by means of a night-letter telegram.

Prof. D. C. Jackson, Jr., K. U., introduced Prof. F. E. Johnson of I. S. C., who said he was glad to be present and he hoped to have all Kansas-Nebraska S. P. E. E. members meet in Ames sometime. At 9:30 P.M. this session was adjourned, and the members went to their respective departmental meetings.

The following departmental meetings were held:

Applied Mechanics, Engineering Drawing, Civil Engineering, Electrical Engineering, Mechanical Engineering, and Shop Practice.

On Saturday, October 28, 1933, the second general session was called to order at 9:40 A.M.

During this session three very interesting papers were presented.

The first paper was entitled "A Pressing Need in Engineering Training." It was presented by Professor John Ise, Department of Economics, K. U.

The second paper was entitled "The Engineer and the Social Order." It was presented by Dr. Seba Eldridge, Professor of Sociology, K. U.

The third paper was entitled "The Preparation of the Engi-

neer for a Place in Organized Society." It was presented by Mr. E. E. Howard, Consulting Engineer, Kansas City, Missouri.

Dean O. J. Ferguson, U. of N., responded to the first paper.

Prof. F. E. Johnson, I. S. C., responded to the second paper.

Prof. F. A. Russell, K. U., responded to the third paper.

Miss Mary Louise Beltz of the Kansas University Fine Arts Department, accompanied by Mr. Geo. Traville, sang. The morning session adjourned at 12:00 o'clock.

Luncheon Meeting

All of the visiting members and ladies were the guests of the Lawrence group at a luncheon given at the University Club, 1433 Ohio Street. Chairman Kloeffler spoke briefly of the early history of the Kansas-Nebraska Section. He introduced the officers for the ensuing year.

Final adjournment was at 1:25 P.M.

The members of the Program Committee who had arranged the program were:

Professors J. A. King, K. U., Chairman,
G. A. Sellers, K. S. C.,
D. H. Harkness, U. of N.

Ferris W. Norris,
Secretary.

Summaries of Departmental Meetings

Applied Mechanics

Professor Colbert, U. of N., Chairman

Topic I. The modification of courses in applied mechanics to benefit students dropping out of college before graduating.

It was agreed that the courses in applied mechanics were of such a general nature and were so broad, that it would be quite difficult to modify the courses to more greatly benefit the students who drop out of college before graduation. It was also decided that the courses as they now stand are of more value to the student, dropping out of school, than the so-called practical courses would be. It was decided that the engineering colleges should not attempt to be trade schools.

Topic II. Evaluation of credits from junior (and small) colleges.

It was decided that the applied mechanics departments of engineering colleges had a perfect right to, and should, question and evaluate credits, in applied mechanics courses, brought from junior (and small) colleges. This conclusion was reached on the basis that the instructor in the small or junior college, would not in general

have had any engineering experience or contacts. Consequently he could not have the perspective that the professional engineering teacher would have. The small college instructor's teaching ability was in no way questioned.

A considerable portion of the discussion period was devoted to the amount of time allotted to applied mechanics courses in the curricula of the several institutions represented at the meeting. It was the opinion of those present that the University of Nebraska does not allot enough time to the teaching of these courses, especially Analytical Mechanics.

Engineering Drawing

Professor Smutz, K. S. C., Chairman

The two topics for discussion were:

1. Evaluating the credits in Drawing from Junior Colleges and High Schools.
11. Methods of Teaching the art of lettering.

Discussion of the first showed:

Nebraska: In evaluating credits, the acceptance or rejection of credits from junior colleges was left to the discretion of the instructors in charge of the drawing courses.

No high school credits were evaluated in drawing.

K. S. C.: An examination at the beginning of the term determined the evaluation.

K. U.: The same method used at K. S. C. was used here.

Discussion on Lettering:

The discussion on lettering proved to be quite interesting.

Each of the schools, including Iowa State, had a different method of teaching lettering.

Professor Kerekes of Iowa State explained the metronome system which he uses in his work.

Professor Hood of K. U. discussed a new approach in methods of teaching lettering at K. U.

K. S. C. and Nebraska, with few exceptions, have the same formal method of instruction.

Civil Engineering

Professor Furr, K. S. C., Chairman

The subjects for discussion were:

I. The content of Civil Engineering Curriculum.
II. Ways and means of the Civil Engineering teacher to enable the student to acquire ample technique and propriety incident to the practice of Civil Engineering.

Professors McNown, Boyle and Russell of Kansas University,

and Professor Evinger of Nebraska, presented prepared discussions and other members of the Section contributed to the discussion from the floor. It was generally agreed that possible improvement in the curriculum should not be sought by adding more specialized subjects; that training in report writing and technical composition of value to students could be obtained by requiring reports as exercises in various professional courses now offered.

Electrical Engineering

Professor Bingham, U. of N., Chairman

Topic: Has the depression changed appreciably the educational objectives and the responsibilities of engineering teachers?

The discussion centered about the advisability of including a greater percentage of non-engineering courses in the electrical engineering curriculum. The time for these courses would be obtained by decreasing the time spent in engineering courses outside the electrical engineering department. "Cultural studies" was a general name given to non-engineering courses. There was much discussion as to the meaning of culture and its value to an engineering student when compared with the value of the technical knowledge which could be acquired in the same time.

Mechanical Engineering

Professor Hay, K. U., Chairman

Topic for discussion: What changes must be made in our objectives and curricula to adequately prepare our graduates for the new social order?

This topic was followed quite closely by the fifteen members present. An informal round table discussion was held in which all participated.

After some discussion, the group quite generally agreed that the technical instruction in engineering should be preceded by a two year pre-engineering course as is now the case in Law and Medicine, and that the technical training should cover a period of three or four years more. However, if it is not possible to have such a scheme and the four year course must be retained, then it would be better to have one basic course in general engineering to be followed, if possible, by specialized graduate work by those desiring a more specialized and comprehensive course.

Shop Practice

Professor Carlson, K. S. C., Chairman

Topic I. How can better co-ordination be obtained between the subject matter in Shop Practice Courses and courses in Design and Administration?

Topic II. Shop Practice Courses for graduate work.

Ten members were present. Professor Sluss, K. U., opened the discussion for Topic No. I. This led to rather free expressions from those present which were enlightening to all.

Professor Bunting, U. of N., opened for discussion Topic No. II. This was a rather original subject and led to a long discussion. Nothing definite was reached but all were very interested. The meeting closed with a hope that these meetings might be continued.

The first meeting of the **Minnesota Section** for the academic year 1933–34 was held at the Minnesota Union, Monday, November 13, 1933. The meeting was preceded by dinner served at 6 o'clock. 39 were present.

Following the dinner the meeting was called to order by President E. W. Johnson. He appointed a Nominating Committee consisting of Professors F. B. Rowley, Chairman, R. W. French and G. H. Montillon.

The principal speaker of the evening was Dr. E. G. Williamson, Director of the University Testing Bureau, who explained the activities of the Testing Bureau and how it is hoped that the Testing Bureau will assist in the vocational guidance of students. Dr. Williamson's talk was followed by considerable discussion which emphasized the lack of acceptable means of measuring the student's capacity for constructive thinking. Mr. Williamson emphasized the need for a series of examinations given at intervals in order to obtain a more satisfactory index of the rate of development of the student.

LORENZ G. STRAUB,
Secretary.

The **North Carolina State College Branch** held the first meeting of the college year on October 16. At this meeting, the following officers for the year were elected: Chairman, L. L. Vaughan, Head of the Department of Mechanical Engineering; Vice-Chairman, R. S. Fouraker, Professor of Electrical Engineering; Secretary, H. L. Mock, Assistant Professor of Mathematics; Corresponding Secretary, T. P. Harrison, Professor of English.

Plans were discussed indicating an interesting and important series of meetings. Names of new members of the Society will be sent in shortly.

State College joins Duke University in deploring the death on October 14 of William Jay Dana, for twelve years Professor of Experimental Engineering in Mechanical Engineering at State College; for the past year, Professor of Mechanical Engineering at Duke. Professor Dana, holding B.S. and M.E. degrees from

the University of Pennsylvania, was held, both personally and professionally, in high esteem at both institutions.

The Pacific Northwest Section.—The banquet room of the Washington Hotel at Pullman, Washington was the setting for a very informal and jolly aggregation of representatives, on Friday evening, April 27, from Montana State College, Oregon State College, Washington State College, the University of Idaho, and the University of Washington. Dean Carpenter of W. S. C. was our host, and Dean Rogers, Vice-President of S. P. E. E., was temporary chairman. The group adopted a brief but adequate constitution and by-laws. The chairman appointed a nominating committee which presented the following officers who were unanimously elected: R. D. Sloan of Washington State College, chairman; J. E. Buchanan of the University of Idaho, vice-chairman; and E. R. Wilcox of the University of Washington, secretary. Dean Tyler invited the Section to hold its next meeting at the University of Washington in Seattle, which invitation was accepted.

With the business so expeditiously concluded the meeting adjourned to the Mechanic Arts Building where Dean Tyler presented some features of the inside and outside of "The Educational Reorganization of the University of Washington, which was followed by some interesting discussion from the floor. Dean Rogers then presented a paper on "The Educational Reorganization of the University of Oregon" which likewise evoked some little discussion. This concluded the meeting for the evening.

At nine o'clock on Saturday morning the Section assembled in the Mechanic Arts Building and was welcomed by President E. O. Holland. Following the President's greetings three papers were presented as follows:

"Teaching Standards in Fundamental Subjects," Professor J. E. Buchanan, University of Idaho.

"Practical Methods in Descriptive Geometry," Professor G. E. Thornton, Washington State College.

"Methods of Developing an Engineering Library," Dean Ivan C. Crawford, University of Idaho.

After lunch a third session was held at which three more papers were presented.

"Trends in Engineering Curricula," Professor E. A. Loew, University of Washington.

"Comparison of Engineering Curricula in German and American Universities," Professor Eric Therkelsen, Montana State College.

"Coordination of Courses in Humanities and Science with Engineering," Professor G. W. Holcomb, Oregon State College.

The papers at both sessions evoked considerable interesting discussion.

The final session, a dinner at the college Commons attended by about fifty including the wives of several of the members of the Section, was brought fittingly to a close by an excellent paper on "The Cultural Values of an Engineering Education" by Professor J. G. Woodburn, Washington State College.

The organization meeting of the Section proved very successful in many ways. It gave all who came an opportunity to inspect the campi of the University of Idaho and Washington State College and the plant and facilities for engineering work at both institutions. It stimulated discussion of many of the common problems which are facing the engineering colleges in the Northwest; and perhaps most important of all, it enabled teachers from the different institutions to meet their colleagues, many of them for the first time, and to lay the foundation for a better understanding and cooperative effort in advancing the standards of engineering education.

E. R. WILCOX,
Secretary.

The **Purdue Branch** held its first meeting of the year October 24, 1933. The subject of discussion was "What Changes Should be Made in Our Engineering Courses to Meet Changing Economic Conditions?" The topic was presented by Professor F. L. Serviss of Chemical Engineering School, Professor W. E. Howland of Civil Engineering School, Professor H. L. Solberg of Mechanical Engineering School, and Professor A. N. Topping of Electrical Engineering School.

A few of the important points brought out by the various speakers might be of interest. The first speaker emphasized the fact that there does not seem to be enough correlation between many subjects taught. Too often a student says that he took 6 credit hours of Calculus just for the credit hours, and is not able later to make use of it in engineering subjects. The second speaker brought out the relation between the social sciences and the engineers' work, showing that the latter requires a different type of mental training. The third speaker brought out the fact that students lose sight of dollar and cents value in the selection of engineering equipment, and that this could be emphasized more by presenting problems along this line in the engineering courses. The fourth speaker suggested the idea that maybe there should not be a fixed time of graduation, but that the student should stay at the university just as long as he can profitably succeed in his courses, and not to look at the degree as the only achievement.

The last speaker also laid emphasis on the fact that all engineers should have courses in economics preferably before the last year so that if they cared to do so they could continue with some of the more advanced courses along that line. The general trend of all speakers was to the effect that we need not change the curricula to improve the chances of graduates securing positions, for if new courses are added, others which are just as important would have to be dropped. The speeches were followed by an interesting discussion.

J. W. GEIGER,
Secretary.

NECROLOGY

FLOYD AUGUST NAGLER

Floyd August Nagler, professor hydraulic engineering and director of the Iowa Institute of Hydraulic Research at the State University of Iowa, died in Iowa City, Iowa, on November 10, 1933. Death came from complications following an emergency operation, on October 6, for a ruptured appendix.

Professor Nagler was born on January 11, 1892, in Howard City, Michigan, and prepared for college in the public schools of Jackson, Michigan. After receiving the degree of Bachelor of Science in Engineering from Michigan State College in 1914, he spent three years in graduate work at the University of Michigan, and received from that institution the degree of Master of Science in Engineering in 1915, and that of Doctor of Philosophy (in hydraulic engineering) in 1917. While a graduate student, he served for a year as a teaching assistant in civil engineering.

After leaving Michigan in June, 1917, Mr. Nagler was with Robert E. Horton of Albany, New York, as an assistant engineer in charge of field and office work, until September, 1920, except for the last nine months of 1918, when he served as a second lieutenant with the Meteorological Section of the Science and Research Division of the United States Army.

Coming to the University of Iowa in the fall of 1920 as assistant professor of mechanics and hydraulics, he was promoted to associate professor in 1922, and to professor of hydraulic engineering in 1927. When the Iowa Institute of Hydraulic Research was organized in November, 1931, to coordinate the facilities available for conducting investigations of unusual scope or complexity in the field of hydrology and hydraulic engineering, he became its first director.

He served the United States Government as drainage engineer from 1921 to 1923, and as senior engineer with the War Department from 1928 to 1930. From 1920 until his death he was engaged as consulting engineer on numerous hydro-electric, flood control, and navigation projects throughout the Middle West.

An unusual native capacity, a thorough education, a passion for truth, and an energy almost without limit, combined to make Professor Nagler a productive scholar of the first rank. His investigations in the field of hydraulic engineering were of most unusual merit, and his many publications were of such distinction as

to bring him even world-wide recognition, and to remain forever an eloquent record of some of his accomplishments. He came to the classroom not only with a knowledge of his subject, but also with a sympathetic understanding of the minds of young men and an ardent desire to contribute to their development. The enthusiasm he showed in the classroom and manifested in all his academic life will remain with his students as a source of inspiration throughout all the years that they may live.

But even when he was busiest in the field of science, Professor Nagler never seemed to lack either the time or the energy for his domestic and civic duties, and many who had only the vaguest understanding of his scientific accomplishments will long remember him as an ideal father and as an outstanding citizen. The hours he spent working about his home were among his pleasantest, and the happiness of his family bore eloquent testimony of their appreciation. He worked tirelessly in his Church, with the Boy Scouts, and in his social clubs, and always with the highest of social ideals and with a faith that never failed him. Abundantly evidenced is Professor Nagler's contribution to the world we live in.

COLLEGE NOTES

Armour Institute of Technology.—Following out the new educational plan which was approved at the Institute a year ago, and which was outlined in an article appearing in the March, 1933, issue of the JOURNAL OF ENGINEERING EDUCATION, President Willard E. Hotchkiss has effected several important changes in the college program. The freshman curricula have been integrated to provide the same course of study for all first year students, postponing the necessity of selecting a department of engineering until the beginning of the sophomore year.

New required courses in business and social subjects have been introduced in the freshman and senior years, organized in a department of Social Sciences under the direction of Professor Carman G. Blough, formerly economist for the Wisconsin State Tax Commission and later head of the accounting department at the University of North Dakota. The new courses, "Business and Engineering Problems" and "Social and Engineering Problems" for freshmen, and "Business Policy" and "Public Policy" for seniors, require full classroom, conference, and preparation time, and seek to impart an understanding of business and governmental procedure commensurate with the importance of those influences in practice of the engineering profession today.

Perhaps the greatest departure in the entire program is the temporary suspension of shop courses from the undergraduate curricula. A committee of the faculty is studying practice and opinion at other institutions and in the professional fields in an endeavor to reorganize shop-teaching at the Institute in accordance with modern tendencies.

As a fourth step in the program, opportunities for graduate study in engineering, science, and architectural subjects have been expanded considerably, and the graduate enrollment is larger than it has been in previous years.

Foremost in the administrative program for further development are extension of the research activities of staff members—both in the various academic fields and in cooperation with public and private outside agencies, and expansion of the department of adult education. The latter, particularly, is looked upon by the administration as a splendid opportunity to broaden the service offered by the school to its community. Evening classes in engineering and technical subjects have shown a healthy tendency to grow in recent years, and the administration feels that there is a vast market for

this kind of service in an active industrial area. Plans to expand this phase of the school's program are being carried forward vigorously.

University of Detroit.—Departmental assemblies are now being held monthly in place of the regular college assemblies in the College of Engineering, University of Detroit. Each professional group, such as aeronautical, architectural, civil, electrical and mechanical, meets under the direction of its department head, with similar groups combined, such as chemical and metallurgical, industrial and mechanical engineering students. The object of these group meetings is to give the students in each branch of engineering an insight into the problems of their particular field. In general, the talks will be along vocational lines, indicating the type of work performed and opportunities available in each professional field. Sophomore students, who are yet undecided in what field of engineering they will specialize, are urged to visit the various assemblies as an aid in their ultimate vocational decisions. The meetings are usually pointed up by the citation of the special problems in each field that engineers have been called upon to solve. This case method has been found to be more practical than a general review of the field.

Drexel Institute.—Professor H. L. Bowman, in charge of the Civil Engineering department at Drexel Institute, Philadelphia, has been appointed chairman of a committee of the Philadelphia Section of the American Society of Civil Engineers which is to propose a schedule of salaries for engineers in this area who are connected with the construction industry. This action is taken in anticipation of the approval of a code for the Professional Engineer Division of the Construction Industry. Under the code a salary schedule, developed through negotiations between employer and employee groups, must be submitted within four months.

University of Iowa.—Following the death of Floyd A. Nagler, Professor of Hydraulic Engineering and Director of the Iowa Institute of Hydraulic Research, on November 10, Byron Bird was appointed Acting Professor of Hydraulic Engineering for the remainder of the school year. Mr. Bird graduated at Iowa State College 1912 and after two years' experience with Alvord and Burdick at Chicago, pursued graduate study in hydraulics at the University of Wisconsin. He has had extensive experience in river improvement and other aspects of hydraulic engineering, chiefly in offices of the Engineer Corps of the U. S. Army. Beginning 1919, he served as instructor, assistant professor, and professor of hydraulic and sanitary engineering at the A. & M. College of Texas and later

as Acting Professor at Iowa State College for one year. More recently he has served as city engineer of Ft. Dodge and when appointed, he was associated with the Currie Engineering Company of Webster City. He is a member of the American Society of Civil Engineers and several other national engineering societies.

Professor S. M. Woodward, Head of the Department of Mechanics and Hydraulics was appointed Director of the Institute of Hydraulic Research and Associate Professor F. T. Mavis was appointed Associate Director to have immediate charge of the laboratory research.

The faculty of the College of Engineering has been drawn into the public works program to a considerable degree. Dean C. C. Williams was appointed at the beginning on the Governor's Advisory Committee for the State. Professor S. M. Woodward served during the summer as consultant to the Tennessee Valley Authority and at present is serving on the Board of Review appointed by Secretary Ickes to consider a comprehensive program for the Mississippi Valley. Professor G. J. Keller has been appointed (full time) by the Governor of Iowa as Engineer in charge of Civil Works for the State. Professor A. H. Holt was selected as advisory engineer upon certain local works under the Civil Works Administration.

Dean C. C. Williams served as chairman of a committee appointed by the Iowa Engineering Society to cooperate with the Brookings Institution in its study of the Iowa governmental organization. The work of this committee covered highway construction and administration, county organization, valuation of utilities, conservation, and sanitation, and served to bring forward through the Institution to the Legislature certain modernization in organization touching engineering matters.

At the opening of the year, freshman English was made optional with foreign language for those who could demonstrate a reasonable capability in writing. A well considered twenty minute test was given at the time of registration as a basis of procedure. About two-thirds of those applying made a satisfactory showing and enrolled accordingly in foreign language. The experiment was found satisfactory and the procedure has been made permanent.

The Water Resources Branch of the U. S. Geological Survey has begun a cooperative study of the streams of Iowa jointly with the Iowa Institute of Hydraulic Research. Mr. R. G. Kasel has been made District Engineer and a separate district created for the state. He and his staff have offices and headquarters at the Hydraulics Laboratory.

Kansas State College.—The personnel of the engineering faculty has experienced but few changes for the past several years. Associate Professor F. J. Cheek returned to his duties with the Department of Architecture this fall after a year's post-graduate work at the Massachusetts Institute of Technology. Instructor J. T. Ware also returned to his duties in the Department of Architecture after a year spent in graduate study at Harvard University. Assistant Professor H. S. Bueche resigned last summer to become Professor of Electrical Engineering at Villanova College, his Alma Mater. His place has been filled by Instructor Fred Schumann who obtained his Master of Science degree from the University of Michigan in 1932. In the Department of Chemical Engineering, Doctor W. L. Faith from the University of Illinois has succeeded Doctor W. L. Brown, resigned.

Three graduate research assistants are employed this year by the Division of Engineering as follows: In the Department of Electrical Engineering, A. W. Rucker; and in the Department of Applied Mechanics, E. J. Peltier and H. T. Nelson.

Curtailment of operating funds has made it necessary to reduce departmental budgets quite materially, but fortunately a special fund is this year available for the purchase of laboratory equipment. One of the items of equipment received recently is a Zeiss photo-elastic strain testing apparatus employing polarized light for test objects up to 10.5 cm. in diameter.

Research work is being done to some extent in every department of the division, either by students working for advanced degrees, graduate students, or by members of the faculty. In the Electrical Department an experimental television station was given a Federal license about a year ago. At present the experimental equipment is being entirely rebuilt and the new equipment is expected to be ready for broadcasting in a few weeks.

Massachusetts Institute of Technology.—Professor Otto Szász of the University of Frankfurt recently arrived from Germany to assume his duties as Visiting Professor of Mathematics at the Institute. During the winter he will lecture on the summation of series, one of the branches of mathematical analysis in which he has gained an international reputation.

For many years he and Dr. Norbert Wiener have worked in close touch, and the two plan to coöperate on various analytical problems during his stay at the Institute.

By maintaining radio communication over the 9,000-mile airway between Rear-Admiral Byrd's headquarters and Cambridge, the Institute will coöperate with the second Byrd Antarctic expedition, which is expected to establish its base on the Antarctic ice this winter.

Special shortwave equipment is being assembled and the Technology station will maintain a daily schedule for transmission of personal communications from members of the expedition. The station will have quarters in the meteorology division of the Guggenheim Aeronautical Laboratory and, in addition to expedition business, daily weather reports will be received for the benefit of the meteorological staff.

The National Academy of Sciences, now grown to be one of the most distinguished scientific bodies in the world, held its autumn meeting at the Institute from November 20–22.

The Massachusetts Institute of Technology has inaugurated a general plan for exchange of professors with other educational institutions and research laboratories, President Karl T. Compton announced today. This is the outgrowth of a suggestion made by Professor D. C. Jackson, head of the department of electrical engineering of M. I. T., in a paper before the Society for the Promotion of Engineering Education in Chicago last summer.

The plan provides for such an exchange arrangement each year for one member of the staff of each of the departments of study in the Institute, embracing the fields of science, engineering, architecture and humanities. The nominations to these exchange professorships will be made by the heads or deans of corresponding departments in the cooperating institutions. Each institution will continue to pay the regular salary of its professor, while on leave. In addition it is proposed to add a modest supplement to the salary of each of the professors involved in the exchanges, in view of special expenses of travel and of temporary living arrangements. Such exchange arrangements may be made with any educational institution in this country or abroad, and also with industrial research laboratories.

The purpose of this exchange plan is to broaden the experience, acquaintance and educational outlook of the men and to disseminate quickly and widely the best educational methods as they become developed in various individual institutions. This exchange will be of mutual benefit to the cooperating institutions, since each may take and use whatever of advantage it learns through this personal contact with the other. Furthermore this plan will tend to overcome a certain tendency in institutions to become "ingrown" or "academic" by providing new contacts with outside personalities and ideas.

In general it is planned to limit these exchange appointments to men who still have years of active service ahead of them, yet who have already achieved some distinction. The first appointments will begin with the next academic year 1934–35.

Purdue University.—The Fourth Industrial Research Conference was held on November 17 and 18; about 250 attended.

Purdue University conferred the degree of Doctor of Engineering upon W. L. Batt, president of the SKF Industries, and O. H. Caldwell, editor of *Electronics*. These degrees were conferred at our Home-Coming on Saturday, November 4. Mr. Batt has been knighted by the King of Sweden and is one of the eminent members of the engineering profession.

Syracuse University.—The sixth bulletin on the theory of Aerial Photographic Surveying, entitled "Supplemental Topics in Connection with Comparator Measurements," by Prof. Earl Church, Associate Professor of Photogrammetry, at Syracuse University, will be available for distribution early in January. In this publication, the author explains a simple and practical method for computing what is called principal point traverse and triangulation from measurements on vertical photographs. Improved methods for calculating the spatial orientations for aerial photographs and for calculating the positions of ground points by spatial intersections, are also discussed.

Virginia Polytechnic Institute.—During the past summer an extensive study was made of the curricula in metallurgy, mining engineering, and engineering geology with a view to simplification and the elimination of unnecessary specialization, which has resulted in too many small classes. As a result, the curriculum in metallurgy has been transferred from the College of Science to the Engineering School and will henceforth be a curriculum in metallurgical engineering. The curriculum in engineering geology will hereafter be known as mining geology and will be identical with that in mining engineering for the first three years. The revisions have resulted in a reduction of 37 credit hours of teaching load to small classes frequently of three or four students. At the same time it is believed that the effectiveness of the curricula has been improved.

Associate Professor F. J. Sette, of the Civil Engineering Department, has been granted a leave of absence for one year to serve as engineer examiner for Virginia for the Federal Administration of Public Works.

Professor John W. Whittemore, of the Department of Ceramic Engineering, is Secretary of Committee C–3 of the American Society for Testing Materials. Professor Whittemore is also secretary of the organization of the brick manufacturers of Virginia and North Carolina, and has been one of the committee to draw up their code under the N. R. A.

A chapter of Tau Beta Pi was installed at V. P. I. on November 24, 1933.

The **University of Wisconsin** Alumni Research Foundation is contributing about $125,000 to the University for the current year in support of research in various departments. These funds are used to pay the salaries of various individuals in the University faculty for one semester during the year, in order to enable them to devote their entire time for that semester to research problems. Four members of the engineering faculty are included in the program: Professor O. P. Watts of the Chemical Engineering Department; and Professors M. O. Withey, J. B. Kommers, and R. J. Roark, all of the Mechanics Department.

The Research Foundation is a non profit-sharing corporation organized by alumni of the University, for the purpose of developing, exploiting, and defending patents granted to members of the University faculty who desire to assign their patents. It has been very fortunate in securing, among its first patents, the valuable Steenbock patent for the use of violet rays in food products, and the royalties on this patent have been very profitable to the organization. Mr. H. L. Russell, formerly Dean of the College of Agriculture, is Director of the Research Foundation.

NATIONAL BUREAU OF ENGINEERING REGISTRATION

CONDUCTED BY

NATIONAL COUNCIL OF STATE BOARDS OF ENGINEERING EXAMINERS

BULLETIN OF INFORMATION

September, 1933

Purpose and Administration

The National Bureau of Engineering Registration is operated as a function of the National Council of State Boards of Engineering Examiners, assisted by an Advisory Board of Representatives from seven national engineering societies. It was established primarily for the convenience of engineers, especially those practicing in more than one State, to minimize the effort and expense of securing registration. The Bureau also constitutes a clearing house for the convenience of the registration authorities of the various States having laws regulating the practice of professional engineering and acts as a reliable source of verified information regarding the professional records of engineers.

The Certificates of Qualification issued by the Bureau are in no sense obligatory for the applicant nor binding upon the State Boards of Registration, nor does the Bureau assume any responsibility to the applicant for securing his legal registration authorizing the practice of engineering in any State. However, the Constitution of the National Council and the engineering registration laws of some states specifically provide for the acceptance of certificates issued by the National Bureau of Engineering Registration.

The following is quoted from the Constitution and By Laws of the National Council:

"Section 6. Committee on National Bureau of Engineering Registration. A National Bureau of Engineering Registration shall be conducted under the direction of the Committee on National Bureau of Engineering Registration. This committee shall consist of five members; three appointed by the incoming President for terms of one, two, and three years respectively, and at the expiration of these terms one member shall be appointed annually by the incoming President for a term of three years; the Chairman of the Committee on Accredited Engineering Schools; and

the Chairman of the Committee on Uniform Examinations for Registration. When the words Registration Bureau are used it shall mean the Committee on National Bureau of Engineering Registration. The Registration Bureau shall be assisted in its work by an Advisory Board of representatives appointed by national engineering societies or associations which may be invited by the Council to participate.

"The Bureau Committee shall adopt forms, rules, regulations, and fees for the Registration Bureau. The Registration Bureau shall investigate and verify the professional records of engineers and issue Certificates of Qualification to engineers who comply with its requirements. The Certificates of Qualification shall be issued by the Registration Bureau in the name of the National Council of State Boards of Engineering Examiners and shall be signed by the Executive Secretary. These certificates shall be available as evidence of qualification for registration as a professional engineer with State Boards of Registration, for membership in national and state engineering societies, in connection with the award of professional degrees by engineering schools, for presentation to clients when soliciting contracts for professional services, for presentation to employers when applying for positions, and for similar purposes.

"Whenever legally possible and in the absence of disqualifying evidence, Member Boards are expected to give due consideration to, recognize, or accept as competent evidence of qualification. the Certificates of Qualification when submitted in support of applications for registration, or as reciprocal endorsement when submitted by applicants who are registered with some other Member Board, or as the equivalent of reciprocal registration certificates or cards issued by Member Boards, or as prima facie evidence of qualification in lieu of examinations.

The Committee on National Bureau of Engineering Registration is as follows:

Hugh A. Kelly, Chairman, Jersey City, New Jersey
D. B. Steinman, New York City
H. D. Mendenhall, Tallahasse, Florida
P. H. Daggett, New Brunswick, New Jersey
O. Laurgaard, Portland, Oregon

T. Keith Legaré, Executive Secretary, Columbia, S. C.
(Executive Secretary of National Council of State Boards of Engineering Examiners)

The national engineering societies are coöperating with the National Council, assisting in the development of the usefulness and efficiency of the Bureau, through an Advisory Board on which the following representatives have been appointed:

American Society of Civil Engineers, George T. Seabury
American Society of Mechanical Engineers, John H. Lawrence
American Institute of Electrical Engineers, Walter I. Slichter
American Institute of Chemical Engineers, J. C. Olsen
Society for Promotion of Engineering Education, R. I. Rees
American Railway Engineering Association, R. E. Warden
American Association of Engineers, C. J. Ullrich

Requirements for Certificate of Qualification

A Certificate of Qualification will be issued only to an applicant who fully complies with the following minimum requirements for a Professional Engineer and who conforms with the other regulations of the Bureau:

A. Graduation from an approved course in engineering of four years or more in a school or college approved by the Bureau as of satisfactory standing; and a specific record of an additional four years or more of active practice in engineering work of a character satisfactory to the Bureau and indicating that the applicant is competent to be placed in responsible charge of important engineering work; or

B. Successfully passing a written, or written and oral, examination designed to show knowledge and skill approximating that attained through graduation from an approved four-year engineering course; and a specific record of eight years or more of active practice in engineering work of a character satisfactory to the Bureau and indicating that the applicant is competent to be placed in responsible charge of important engineering work; or

C. A specific record of twelve years or more of active practice in engineering work of a character satisfactory to the Bureau and indicating that the applicant is qualified to design or to supervise construction of engineering works and has had responsible charge of important engineering work for at least five years and provided applicant is not less than thirty-five years of age.

In passing upon the professional record and experience of an applicant the Bureau will construe "professional engineer" or "active practice in engineering work" as follows:

The term "Professional Engineer" shall mean a person who, by reason of his knowledge of mathematics, the physical sciences and the principles of engineering, acquired by professional education and practical experience, is qualified to engage in engineering as hereinafter defined.

The practice of professional engineering includes any professional service, such as consultation, investigation, evaluation, planning, design, or responsible supervision of construction or operation, in connection with any public or private utilities, structures, buildings, machines, equipment, processes, works, or projects, wherein the public welfare, or the safeguarding of life, health, or property is concerned or involved, when such professional service requires the application of engineering principles and data.

The mere execution, as a Contractor, of work designed by a Professional Engineer or the supervision of the construction of such work as a foreman or superintendent shall not be deemed to be active practice in engineering work.

Fees

The charges for services of the Registration Bureau are as follows:

The fee for investigating and verifying the professional record of an engineer is $10.00, which fee must accompany application and will be retained by the Registration Bureau regardless of whether or not the results of the investigation warrant the issuance of a Certificate of Qualification.

When an application for a Certificate of Qualification is approved, the applicant will be so notified by the Bureau and upon payment by him of an additional fee of $5.00 the Bureau will furnish the applicant with a photostatic copy of his verified record and also with a separate Certificate of Qualification suitable for framing.

Additional photostatic copies of verified professional records will be furnished by the Registration Bureau for $3.00 each. These certified copies of professional records may be sent direct by the Registration Bureau to State Boards of Engineering Registration or other parties designated.

An applicant whose status is classified under provision *"B"* of the requirements for a Certificate of Qualification and who has not passed an engineering examination satisfactory to the Registration Bureau, will be notified to this effect and, if desired by him, the Registration Bureau will appoint an examining board in the State of which applicant is a resident, to conduct the examination in accordance with standards approved by the Registration Bureau, the cost of such examination to be paid by the applicant.

An independent investigation such as is conducted by the Bureau often requires considerable time (two weeks to six months); therefore, it is suggested that an engineer not wait until he actually needs a Certificate of Qualification but that he file his application with the Bureau whenever convenient, so that a certified copy of his professional record may be available at any time for presentation to State Boards of Registration with which he desires registration, or for any other appropriate purpose.

Information secured from references is for the confidential use of the Bureau in verifying and passing upon professional records of applicants and the source and character of this information will not be divulged except in special cases when desired by legally authorized State Boards of Registration.

Applications for Certificates of Qualification must be made on forms furnished by the Bureau and filed with the Executive Secretary, National Bureau of Engineering Registration, P. O. Drawer 1404, Columbia, S. C.

BOOK REVIEWS

The "Principles of Metallurgy," by Messrs. D. M. Liddell and G. E. Doan, just published by McGraw-Hill Book Company, is an up-to-date text of the general type of Roberts Austens' classical "Introduction to the Study of Metallurgy." The volume contains something over 600 pages, and is divided into 3 main parts: "Materials Consumed in Metallurgy," "Extractive Processes and Apparatus," and "Physical Metallurgy." A brief introductory section outlines the status of metals in the ancient world, and then passes abruptly to modern metallurgy as applied chemistry and physics. Another excellent chapter emphasizes the necessity of a profitable basis of operations, and other economic features of fundamental importance in the conduct of the art.

The chapter headings in part I are as follows: "Ores," "Slags and Fluxes," "Refractories and Furnace Linings," "Fuels and their Use," "Air and Water Supply." Ores, not directly defined, are discussed from the metallurgical standpoint, not from the geological. The space given to the next three chapters is too limited for more than a rather elementary treatment. Air and water supply is given more space relatively in both theoretical and practical discussions.

"Extractive Processes and Apparatus" is treated in 7 chapters, well chosen and logically arranged: Chapter VIII, "Ore Preparation for Extraction Processes" describes briefly the essential features of the important devices for the operations of ore dressing, together with the theoretical principles involved, and the advantageous applications, often an important detail. In Chapter IX roasting is very well presented, and the important features of the more prominent furnaces and other roasting and sintering devices and practice are described somewhat in historical order. Making pig iron in the blast furnace is very clearly though briefly described as an example of reducing smelting. Refining of the crude metals is illustrated by the Bessemer and open hearth processes for steel, also by the converting of copper matte. Distillation processes as used for zinc and mercury occupy a brief final section. In Chapter X, "Hydrometallurgical Apparatus and Processes," the chlorination and cyanidation processes for gold and silver, and various methods for copper leaching, and for lead and zinc hydrometallurgy are briefly discussed; and then hydrometallurgical apparatus in general is described. Chapter XI, "Electrometallurgy and Electrometallurgical Apparatus."

describes electrolytic processes and apparatus briefly but satisfactorily. Electric furnaces are rather briefly mentioned only. Chapter XII covers "Briquetting and Sampling"; and Chapter XIII, "Dust and Fume Control," which are important subjects. Chapter XIV is a very satisfactory one on "The Measurement of Temperature."

Parts I and II of the text, above outlined, in general, were written more as an outline of metallurgy for students of other branches of engineering than as a theoretical introduction for students specializing in metallurgy. Part III, on "Physical Metallurgy," covers an introductory study of metals and alloys in such a way, with sufficient detail, and with subject matter very well brought up to date, as to be well suited as an introductory text for students going on to specialize in metallurgy, or as a text for students who merely wish to secure some fundamental knowledge of metals and alloys and their treatments, etc., as materials of construction.

Nearly 100 pages is devoted to Chapter XV, "The Metallic State," in which Dr. Doan has discussed the states of aggregation of matter, especially the solid state, the crystalline character and forms of solid metals, and the various origins of metallic structure, listed the physical properties, described the mechanism of plastic deformation, and the methods of X-ray crystal analysis both of single crystal and ordinary or polycrystalline metal, etc. In Chapter XVI, "Alloys," the purpose of the author is stated "to develop a system . . . for predicting (from examination of the constitutional diagram) what will be the normal internal structure of any certain chosen alloy." The alloy phase diagram is excellently well presented and discussed in a clear manner easy to follow. The "Properties as Related to Structure" of alloys are discussed in the next chapter from both the theoretical and practical standpoints, including such properties as strength and hardness, formability, electric conductivity, magnetism, corrosion, etc., etc. The "Technology of Shaping Metals" is very briefly outlined in Chapter XVIII (18). Perhaps the most important method of shaping in the solid state, that is, rolling, has received very scant attention. Chapter XIX, on "Other Physico-Metallurgical Processes" describes mainly physical testing, and heat treating of metals and alloys. The final chapter of this section and of the book is a presentation of "Slags, Matte, Bullion, and Speiss," largely on the basis of the constitutional diagrams. This chapter is mainly of interest to the student who is to specialize in metallurgy, furnishing data for study and reference missing from the earlier chapter on slags and fluxes.

S. L. GOODALE

"Direct and Alternating Currents," E. S. Loew, E.E. McGraw Hill, 1933. 656 pages. Price $4.50.

The book is divided into two parts. Part one is Direct Currents and is made up of seventeen chapters covering 288 pages. The first ten chapters deal with D. C. Currents and chapters 11 to 17, inclusive, deal with D. C. machinery. Part two is Alternating Currents and is made up of sixteen chapters covering 359 pages. Chapters 18 to 24, inclusive, deal with A. C. Circuits while chapters 25 to 32, inclusive, deal with A. C. machinery. Chapter 33 deals with electron tubes and rectifiers.

At the end of each chapter a number of representative problems are included. The author has reduced the mathematical discussions of electrical laws to their simplest forms.

The text is profusely illustrated by cuts and diagrams which helps materially the understanding of the descriptions and laws covered in the text matter.

The author has done a very commendable piece of work and the text should find a large field for non-electrical students wishing a general course covering the electrical engineering field.

P. E. Rush.